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WEED CONTROL*

The war has been responsible for intensive investigation in many directions and much of this work has not yet been divulged. That concerned with nuclear energy is best known to the public through the atomic bomb and its direct bearing on international relations, but a parallel case is to be found in the chemical fields. Biological warfare was always a possibility, with the destruction of crops as one of its objectives. In the U.S.A. a biological warfare project was initiated and research along similar lines was conducted in many countries. As a result, large numbers of compounds were synthesized and tested. One result of this work has been the discovery of a dual reaction of the plant to such substances ; in certain concentrations they are lethal ; in very low concentrations, of the order of one part in several million, they produce responses of a different nature but which may broadly be designated as growth regulation. They are thus associated with that as yet somewhat nebulous group of substances which includes vitamins, hormones and auxins. Here is a large field for pure research, but an outlet in practical application has been found before the how and why are fully understood. Medicine takes growing account of vitamins, and hormones and auxins are being applied in agriculture and horticulture. Increased knowledge of these substances is, too, effecting another change. Originally isolated from the products of living matter, as auxins A and B were by Kögl from animal urine, these and a wide range of associated substances have been produced synthetically.

One practical outcome of this work has been to employ some of these substances in lethal concentrations for the purpose of killing weeds, thus adding a large range of potential weed killers to numerous inorganic substances previously in use. And not the least advantage of these newer substances is their selectivity ; that is, their power to kill certain plants while being inocuous to other plants and to animals. Of these 2, 4-D, the base of which is 2, 4-dichloro-phenoxyacetic acid, is perhaps the best known. Advantage has been taken of the discovery to initiate an extensive programme of experiments in killing weeds in many parts of the world, and a vast literature has already come to hand on this subject, a literature which it is no longer possible to review individually. Cane has not formed an exception,

*The International Sugar Journal, 1947, p. 315.

and series of experiments have been conducted both in Mauritius and Hawaii, some account of which has been previously given.(1)

More recently, H. Evans(2) has recorded his trials in controlling a further group of weeds, *Pœderia fœtida, Ipomœa cairica, Asystasia gangetica, Thunbergia fragrans* and *Bignonia unguiscati*. The varied results indicate the selectivity of the different substances ; in the case of the last-named weed, 10 per cent. sodium chlorate was the only fully efficient killer. This and the fact that many of the killing agents pass under proprietary names prohibit profitable review of the results.

The efficiency of many of these substances in killing weeds is undoubted ; but their use in agricultural work offers a case of practice outrunning theory. Little is known of the why. Their selectivity permits the eradication of the weed without direct injury to the crop plant. But these are not the only organisms concerned ; there are all those organisms which go to form the soil micro-fauna and flora. It is hardly likely that the same selectivity will not be shown in the case of these. Indeed, there is a massive weight of evidence, collected by Waksman, (3) to show that bacteria and other micro-organisms produce chemical substances which inhibit the metabolic activities of other micro-organisms, an inhibition to which the term antibiosis is applied. Perhaps the best known of these is Penicillin, owing to its medicinal value. The whole process of the decomposition of animal and plant residues in nature and in the various methods in use for the purification of sewage, it is suggested, is dependent on these substances, and there is even evidence that viruses fall within the range of such inactivators. How do these antibiotic substances work? May not the soil micro-organisms which develop them, including the fungi of which the mycorrhiza form one group, pass them on to the crop plant to establish in it a resistance to disease ? What relation do these antibiotic substances bear to the growth-regulating substances now coming into use for weed eradication ? Into the balanced biological economy of the soil substantial quantities of the growth regulating substances are being injected with an unknown reaction on that economy. There is here an obvious danger which would suggest cautious action.

Much of the work on these growth-promoting and antibiotic substances has not yet been made public, but the subject is treated in a large number of recent papers. The effect of treating soil and seeds on germination is considered in two,(4) while one deals with their persistence in the soil.(5) Disappearance was, in these trials in the field, accomplished in 68-80 days. It is clearly desirable to know a great deal more as to a possible selective influence on the micro-flora of the soil, yet no mention of such tests is made in the eight lines of investigation recommended by the U.S. Department of Agriculture,(6) bees and other beneficial organisms alone being considered.

References

(1) *I. S. J.*, 1947, p. 146
(2) Rev. Agric. l'Ile Maurice, 1947, 26, pp. 3-10.
(3) S. A. Waksman. "Microbial Antagonisms and Antibiotic Substances". (The Commonwealth Fund, N.Y.), 1945.
(4) C. L. Hamer, *et al.*, *Botanical Gazette*, 1946, pp. 352-361 ; and R. Allard *et al.*, *ibid.*, pp. 575-583.
(5) H. R. DE ROSE, *ibid.*, pp. 583-589.
(6) "D.D.T. : The Synthetic Insecticide" (Chapman and Hall). 1946.

CONTROL OF BANANA WILT DISEASE

Some years ago I reported in these columns an unusually interesting and important field experiment on the control of (wilt) disease of bananas (*Fusarium oxysporum cubense*), which I had seen while travelling in Honduras.(1) This consisted in flood-fallowing an area of about a hundred acres which had gone out of cultivation because of wilt disease. The area was empoldered (contained within earth embankments) and divided into sections, each of which was being kept submerged for a different period of time. This experiment was based on the observation that soil fungi, such as *F. oxysporum*, require oxygen to live, when highly infected soil was submerged for one month under two feet of water, no living *Fusarium* could be found in it. At that time I wrote : "The outcome of this experiment will be awaited with the greatest interest by all associated with the extensive alluvial banana lands of Central America". Already, at that time (1940), it had been found that in new land, built up by the sedimentation of controlled flood water, and therefore subjected to several inundations, the incidence of wilt disease was negligible.

Recently I had news of the experiment from a scientific correspondent, Dr. V. C. Dunlap, to whom I now make acknowledgment. Areas originally flooded for six, twelve and eighteen months have been producing fruit for nearly six years, and it is considered that several years of good production still lie ahead. Scattered cases of wilt disease did appear after ten to eighteen months, but the subsequent spread of the disease was slow. *As* in many good soils, a mat or stool may show disease in one plant while all the other plants apparently remain unaffected for two or three years. It is considered improbable that the method of flood-fallowing will ever be successful in acid soils (in which plants succumb readily and in which the fungus may spread with great rapidity), but the system is being extended to other areas considered to be suitable.

Much credit is due to the officers of the United Fruit Co., for their enterprising experimentation on a large scale.—(Letter from C. W. Wardlaw, to *Nature*, 160, 405 (1947).)

(1) *Nature*, 147, 313 (1941).

NOTICE TO SUBSCRIBERS

Through unavoidable delays due to printing difficulties this issue of the Journal was released from the press on 31st December, 1948.

THE WATER AND AIR RELATIONS OF SOME TRINIDAD SUGAR-CANE SOILS
PART II

BY

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(I) Introduction

In Part I of this article,** experimental field and laboratory evidence was presented which demonstrates the peculiar water and air relations of a sandy soil and a clayey soil representative of the sugar-cane lands of the Northern Plain of Trinidad. Most of the experimental material was drawn from Field F 88, Frederick, Caroni Estate, which comprises clayey soil (Cunupia Clays) in its western part and sandy soil (Washington Loams) in its eastern part.

(1) During 1943 and 1944, studies were made on six different occasions of the moisture and air profiles of the two kinds of soil. The results showed that the sandy soil maintains a rigid porous structure or "skeleton", having large non-capillary porosity throughout the 2-foot profile, whereas the clayey soil has a collapsible structure which shrinks during the dry season; its non-capillary porosity (apart from cracks) is very small and diminishes down the 2-foot profile from about 10 per cent. to zero at the 12 ins. depth.

The *sand profile* was inadequately aerated when examined in wet weather, the non-capillary pore-space being largely occupied by water. This implies drainage impedence in the subsoil.‡ When examined in very dry weather, both the non-capillary and part of the capillary pore-space was occupied by air, implying excessive aeration. Available moisture content was then very low though it reached wilting stage only during the very driest weather. This implies severe drought in the dry season.

The *clay profile* was also inadequately aerated in wet weather, presumably also because of drainage impedence, owing mainly to its impervious structure. In dry weather, aeration was just as great as in the sandy profile, however, because of the development of deep cracks. Available moisture content in the surface layers was even lower than in the sand because cracking had enhanced the drying so that the wilting stage was reached quicker.

(2) The results recorded above were checked by a reconsideration of soil moisture data collected at the same sites during 1927 and 1928 when the soils were sampled weekly, top and second foot layers, and their gross moisture contents determined in the laboratory. The periodic data gave a clear picture of moisture and air fluctuations within these two layers for an exceptionally wet year (1927) and a very dry year (1928); they thus indicated the extremes that might be realized in the texturally-contrasted soils.

The data obtained in this second investigation fully substantiated and extended those obtained in the first. They proved that the sandy soil suffers drainage impedence in wet weather and excessive aeration in dry periods, whereas the clayey soil is waterlogged in wet weather and excessively aerated, even in the second foot layer, during prolonged dry periods. This is because of severe cracking. In spite of its greater water retentivity, the clay soil contained lesser amounts of available water in dry weather than the sand, which is contrary to expectation. This also is a result of cracking which encourages rapid drying.

The moisture and air relations of sandy and clayey soils thus depend on their intrinsic physical properties as well as on variations in the rainfall. It was found that both soils began to dry out when the mean rainfall of the previous 28-day period fell below about 4 ins., and that the dry soils began to gain moisture when the mean 28 days' rainfall rose above about 2 ins.

(3) The next series of investigations, mostly carried out in 1944 and 1945, concerned the measurement of infiltrability of the surface soil layer and of permeability of the deeper soil and was performed in the laboratory on samples collected in cylinders in the field without structure disturbance, as well as on samples examined *in situ*. The results showed that the rate of infiltration is somewhat greater, and the rate of deep percolation very much greater, in the clay than in the sand. This finding also was contrary to expectation; it is attributed to the angular-aggregate structure imparted to the clay by cracking. This structure is easily destroyed at the soil surface, however, by compaction and puddling or smearing by rain. Furthermore, the sandy soil tends to silt up during the downward passage of water. Its surface infiltrability is also liable to be diminished by the formation of hard crusts.

(4) Finally, detailed observations on cracks, cracking and crack-closure, made during 1944-45, were recorded and their important functions discussed. Soil-cracking is greatly enhanced when the natural surface organic layer of a soil is lost by wastage and erosion, or becomes mixed with subsurface soil by cultivation, and when the land is exposed by bare fallowing. Its important effects on water and air relations, particularly of clay soils, can scarcely be overestimated.

In the second part of the article that follows, further consideration will be given to the role of rainfall in soil wetting, regarded mainly from the point of view of periodicity and shower-intensity. Data obtained at the College Meteorological Station (which is only 3

* Professor of Chemistry and Soil Science.
† Post Graduate Colonial Office Scholar, 1943-45.
** *Trop. Agriculture*, Trin. 1947, XXIV. Pp. 76-87.
‡ The sand profile is really composite and consists of recent sandy river alluvium sharply overlying older marine clayey alluvium.

miles away from the scene of the field investigations) will be applied to the monthly rainfall data recorded at Caroni, and an attempt will be made to draw therefrom further conclusions concerning various aspects of water infiltration and percolation in sandy and clayey soils respectively.

(II) Characteristics of the Rainfall at Caroni

(1) *Gross Monthly Rainfall*: It has been noted that the year 1927, when soil moisture and soil air fluctuations were first periodically measured in Field F 88, was an exceptionally wet year, there being 11 wet months and only one dry month. By contrast, the next year, 1928, was an exceptionally dry year, there being only 8 wet months and 4 dry. Thus the data obtained for these two contrasted years provide extreme limits by means of which the soil moisture and soil air conditions for any other year may approximately be gauged. In Table I are set out the rainfall characteristics for the 20-years' period, 1926 to 1945, for Frederick, Caroni. The data are arranged in order of decreasing total rainfall. The numbers of dry, intermediate and wet months are given, as well as the average rainfalls in a dry month and in a wet month. Finally, the stages of growth and the yields obtained for the cane-crop grown in Field F 88 are given for each year during which the crop was on the land.

It is evident that the number of dry months at Frederick, Caroni, has varied between 6 and 1, and wet months between 11 and 6, the remaining months of the year being intermediate but never more than two in number and usually one or none. Thus the dry season is always sharply demarcated from the wet season, the average monthly rainfall in a dry season being much lower than Mohr's limit (*viz.* 2.4 ins.). By contrast, the average monthly rainfall in a wet season is more than twice as high as Mohr's limit for a wet month (*viz.* 4.0 ins.).

TABLE I

ANNUAL AND MONTHLY RAINFALL DATA: 20 YEARS' PERIOD, 1926-1945.

(YEARS ARRANGED IN ORDER OF INCREASING DRYNESS)

CARONI SUGAR ESTATE, TRINIDAD. FIELD F 88

YEAR	TOTAL RAIN-FALL (ins.)	Monthly Rainfall Category No. of months			Average monthly rainfall		SUGAR-CANE CROP	
		Dry	*Intermd.*	*Wet*	Dry mths. (ins.)	Wet mths. (ins.)	Stage	Yield (tons. ac.)
WET YEARS								
1942	100.2	4	0	8	1.2	11.9	(Abandoned)	—
1938	96.9	2	1	9	1.9	10.0	Plants	60.6
1927	95.0	1	0	11	1.6	8.5	3rd ratoons	5.4
1933	90.7	3	1	8	1.6	10.2	2nd ,,	17.8
1945	90.2	3	1	8	1.6	10.3	1st ,,	28.4
1941	89.2	4	0	8	1.2	10.6	1st ,,	29.0
1944	87.9	3	2	7	1.3	11.2	Plants	25.8
MEDIUM WET								
1932	83.1	1	1	10	1.4	7.8	1st ratoons	23.4
1936	83.0	3	1	8	1.5	9.5	1st ,,	17.0
1940	79.5	3	1	8	1.1	9.1	Plants	24.6
1943	76.1	3	0	9	1.3	8.0	(Abandoned)	—
1939	74.9	4	1	7	1.5	9.3	1st ratoons	12.9
1935	71.1	4	1	7	0.6	9.3	Plants	47.2
DRY YEARS								
1931	69.7	5	0	7	1.0	9.2	Plants	32.2
1929	67.4	4	1	7	1.1	8.4	1st ratoons	21.2
1937	62.1	3	1	8	0.7	7.0	—	—
1926	61.9	5	0	7	0.9	8.2	2nd ratoons	6.2
1928	60.8	4	0	8	1.4	6.9	Plants	28.4
1934	59.6	6	0	6	1.2	8.7	—	—
1930	53.2	4	2	6	1.6	6.8	—	—
MEANS:								
Average year ...	77.6	3.5	0.5	8	1.3	9.0		
Wet ,, ...	89.6	3	1.0	8	1.5	10.0		
Dry ,, ...	65.7	4	0.5	7.5	1.1	8.0		

NOTE: (1) Each cane crop was reaped during the early dry season of the year following that for which the yield is recorded above; most of the growth was made during the recorded year.

(2) The cane varieties grown were changed three times during the 20-year period; prior to 1929, D 16 was grown during 1929 to 1931, B 6032, and from 1932 to 1944, BH 10/12. In 1945, B 34104 was introduced.

An attempt to correlate cane yields with monthly rainfall (Table I) failed to reveal any obvious connection, doubtless because so many other growth factors are involved. Nevertheless, the records indicate that medium-wet years are the best and dry years the worst for cane production in Caroni. Thus, the crop in Field F 88 was abandoned for three very dry years (that were not War years) out of a total of 10 dry years recorded in the table. Information on gross rainfall, however, is not sufficient for the purposes of crop ecology; it is necessary to know something about the periodicity of the rain and the amount that evaporates without sinking into the ground. For these purposes, an automatic recording rain-gauge and some sort of evaporimeter should be installed within or near the experimental area.

(2) *Evaporation* : At the College, it has been estimated from actual evaporimeter data that about 60 per cent. of the total annual rainfall is lost by evaporation from the surface of a fallow plot comprising fine sandy soil.* It was found that there is not much difference in the percentage loss during the dry season as compared with the wet. Applying these results to the Caroni rainfall data, it would appear that, in an average year, about 47 ins. of rain are lost by evaporation out of a total of 78 ins., leaving 31 ins. of "soaking" rain which either penetrates into the ground or partly penetrates and partly runs away off the surface. The mean monthly evaporation is thus about 4 ins., and mean monthly penetration *plus* run-off (if any) is only about 2.6 ins. of rain which is an expectedly low amount. Hence only mean monthly rainfalls of over 4 ins. will provide a surplus that is effective in supplying water to the soil for the use of the cane plant. This critical value is identical with the value based on Mohr's formula. It also agrees with the results described in Part I (Fig. 2) in that soil wetting was found to occur only when the moving average monthly rainfall rose above about 4 ins.

* The Evaluation of Soil Moisture, F. Hardy, *Trop. Agriculture*, Trin. 1946, XXIII, Pp. 66-75.

The type of rainfall at Caroni is convectional. The daily rains usually start at 10.30 a.m. to 11.30 a.m. and are generally over by noon. Occasional spasmodic before-dawn and afternoon rains occur in the wet season, but most evenings and nights are rainless and clear. Between 10 p.m. and 6.30 a.m. humidity is 100 per cent. and dew forms freely. Evaporation of soil water thus takes place mainly during daylight though daily humidity seldom drops below 50 per cent. In the dry season persistent breezes greatly enhance evaporation.

(3) *Analysis of Rain Showers* : The amount of soil water evaporation at the College fallow plot has been found to be approximately equal to the rain which falls as light showers having intensity below 0.41 ins. per hour†. It may therefore be assumed that rain which falls more quickly than this either all soaks into the ground or partly runs away off the land. The lower limit for run-off rain has tentatively been accepted as 0.75 ins. per hour. An analysis of rain showers at Frederick, Caroni, for an average year is given in Table II, based on the assumption that the periodicity of the rain is the same there as at the College which receives about the same total amount of rain.

From the data in Table II, the following rainfall characteristics have been deduced for Frederick, Caroni.

(A) *During a normal wet season* : (May to December)

(a) rain showers occur once in every 1138 minutes (19.0 hrs.),

(b) each shower lasts 44.4 minutes on an average ;

hence (c) only 56.2 minutes in every 24 hours are rainy and occur generally around noon.

† Seasonal Fluctuation of Soil Moisture and Nitrate, F. Hardy, *ibid.*, 1946, XXIII, Pp. 40-49.

TABLE II

ANALYSIS OF RAINFALL DATA FOR FREDERICK, CARONI

(BASED ON ANALOGOUS RESULTS OBTAINED AT THE COLLEGE METEOROLOGICAL STATION)

Shower category	Total rainfall (ins.)		Number of showers		Average rainfall per shower (ins.)		Duration of each shower (minutes)	
	Wet season	Dry season	Wet season	Dry season	Wet season	Dry season	Wet season	Dry season
Torrential	14.4	0.9	25	2	0.576	0.450	46	36
Medium	15.2	2.7	45	30	0.338	0.090	35	9.5
Light	36.8	8.0	240	87	0.154	0.092	46	28
Totals	66.4	11.6	310	119	—	—	—	—

Torrential showers, 0.75 ins. per hour and over
Medium showers, 0.74-0.41 ins. per hour } "Soaking" showers
Light showers, 0.40 ins. per hour and under

(B) *During a normal dry season* : (January to April)

(a) rain showers occur once in every 1452 minutes (24.2 hrs.),

(b) each shower lasts 23.5 minutes on an average ;

hence (c) only 23.3 minutes in every 24 hours are rainy and occur generally around noon.

If it be assumed that light showers all evaporate and are therefore not effective in plant growth, whereas medium and torrential showers are likely to be effective, then, ignoring light showers :—

(A) *During a normal wet season* :—

(a) *effective* showers occur once in every 5040 minutes (84.0 hours),

(b) each shower lasts 39 minutes on an average ;

hence (c) only 11 minutes in every 24 hours are *effectively* rainy.

(B) *During a normal dry season* :—

(a) *effective* showers occur once in every 5400 minutes (90.0 hours),

(b) each shower lasts 11.2 minutes on an average ;

hence (c) only 3.0 minutes in every 24 hours are *effectively* rainy.

The mean magnitude of a wet season shower is 0.214 ins. and of an effective or "soaking" shower, 0.423 ins. Soaking showers fall on the average only once in about 3½ days ; their mean intensity is 0.65 ins. per hour, since each lasts only 39 minutes. These values may be applied in an attempt to solve the theoretical problem of how much rainfall is required at the beginning of a wet season to saturate the soil to a given depth, or to raise its moisture content to any particular level. For this purpose, however, it is first necessary to know the magnitudes of certain physical constants for the soils in question.

(III) Characteristics of the Soil

(1) *Soil constants* : Numerical values for mean soil moisture contents are set out in Table III for the top 24 ins. layer of sandy and clayey soils of Field F 88, Caroni.

From the values in Table III, it is evident that, in order to raise the moisture status of the top 2-foot layer from wilting stage to field capacity requires, in theory, about 2.4 ins. of effective rain for sandy soil and 4.5 ins. for clayey soil, and to raise it to full saturation needs 6.8 ins. of effective rain for the sand and 5.4 ins. for the clay. Assuming that "soaking" showers alone are capable of penetrating, then the number of average effective showers, regularly spaced, needed to wet the soils uniformly to the levels indicated would be about 6 and 11 for field capacity and 16 and 13 for full saturation; these would fall within about 21 and 38 days in the first case and 56 and 45 days in the second. These are average theoretical values, however, and have little practical significance because the Caroni rainfall is far from regular and its periodicity and intensity are unpredictable. Nevertheless the conclusions reached in this discussion have considerable bearing on the interpretation of rainfall data in relation to soil wetting.

For example, they indicate that, when rain showers are evenly distributed, both the sandy soil and the clayey soil have sufficient capacity for absorption, storage and evaporation fully to cope with the average rainfall incident at Caroni Estate leaving no surplus for run-off.

(2) *Infiltration rate* : For rain water to penetrate, it must first infiltrate into the soil surface. The infiltrability of soils varies greatly depending on the physical structure of the surface layer. This is partly decided by the presence or absence of organic plant residues of different kinds. It is also greatly affected by tillage which imparts "tilth".

The soils under consideration mostly present bare surfaces generally devoid of litter because of the customary practice of trash burning. They are usually fairly free from weeds. Hence, during dry weather, cracks soon develop and the top layer of soil rapidly breaks up into countless angular fragments or "false crumb" which just as quickly run together again on wetting. When the soil is cracked, its infiltrability is high, as was proved by direct measurement (see Part I, Section VI). Values of 8.0 and 8.7 ins. of water per hour respectively,

TABLE III

SOIL MOISTURE CONSTANTS : Field F 88. Caroni

(mean values for top 24 ins. layer)

Soil constant	Weight per cent.		Volume per cent.		Equivalent of rain for 24-ins. layer	
	Sand	Clay	Sand	Clay	Sand	Clay
Wilting coefficient	11.0	21.0	15.1	28.0	3.6 ins.	6.7 ins.
Field capacity	18.0	35.0	25.1	46.6	6.0	11.2
Aeration limit	—	—	33.5	40.6	8.0	9.7
Saturation capacity	30.8	37.7	43.5	50.6	10.4	12.1

were given by sandy and clayey soil samples which had been soaked overnight in water. These results imply that the soils after cracking followed by temporary wetting can absorb the heaviest showers.*

In the course of time, however, continued beating of rain impacts and puddles the soil surface and markedly diminishes its infiltrability. These effects may readily be demonstrated in the laboratory merely by smearing the surface of the ring sample with the finger which at once reduces the rate of water entry to zero. On drying, puddled soils often develop hard impervious crusts which shed water, especially the silty and fine sandy kinds of soil.

The rate of infiltration of water into the larger and deeper cracks is gradually reduced through their closure by plugs of soil, vegetable detritus and burnt trash (see Part I, Section VI). These plugs occupy only the upper few inches of the fissures. At first they are loose and porous; later they become compressed so as completely to seal the crevices. Only severe drying will then re-open the cracks along their former courses.

The effect of organic layers on infiltration is generally considered to be great. A highly humic soil usually exhibits a porous, water-stable, open crumb structure. Cracks which develop on drying are very tiny and profuse. Puddling and crust formation do not readily occur in highly humic soils, so that their infiltrability is much less affected by the vagaries of the weather than humus-deficient soils. The presence of leaf litter and decaying plant residues is believed also to enhance infiltration. In the peculiar case of fresh cane-trash, however, the formation of an impervious sheet of overlapping dead leaves that have not yet disintegrated, prevents the free passage of water downwards into the soil. It is advisable to avoid this happening by ranging the trash into rows (rollers or boucans) and spreading it only after it has partially decayed.

The Caroni soils could not be considered to be highly humic; their content of organic matter in the top 6 ins. layer is about 2.0 per cent.,† with carbon-nitrogen ratio 8.0. Due to continued cultivation and self-mulching through cracking, the organic matter content is fairly constant down to the 12 or 15 ins. depth. Because of their marked propensity to cracking, it is a matter for conjecture whether or not the Caroni soils could be economically improved by merely increasing their organic matter content.

It would seem that their infiltrability in their present condition depends mainly on the weather. When the rainfall consists of intermittent, short, heavy showers alternating with long sunny intervals, provided the land is not too heavily shaded with foliage, surface cracking may adequately cope with all the rain that falls, whereas when the rains are continuous, even if relatively light, surface cracks remain sealed and puddling occurs, so that run-off rather than infiltration is favoured.

(3) *Percolation rate*: The downward passage of water that has infiltrated into the surface of a soil depends on the permeability of the subsoil which varies greatly in different soil-types. For the soils in question, the permeability constant, as determined in the field for the upper 18-inch layer, was found to be considerably higher in each case than the infiltration capacity, particularly for the clay soil which was more than ten times as permeable as it was infiltrable. This implies that the downward movement of water that has entered the surface is not impeded in either case by poor drainage in the subsoil, at least down to the 18-inch depth.

The sandy soil overlies a geological clay substratum at 6 feet at the site where the measurements were made, so that, in rainy weather, it rapidly fills up from below with water. Thus, from the end of July to the end of December in the wet season of 1946, the water-table lay mostly between 40 and 50 ins. below the crest of the cambered bed but on no occasion was it found to be higher than 30 ins. The level of the drain bottom below the crest is 34 ins., so that the water-table within the bed cannot rise much nearer to the surface than 30 inches in the sandy soil, at which point excess of free water percolates laterally into the drains and so escapes.

The features of the clay soil are very different. A deep auger hole was bored on the occasion of each visit and the level below the bed crest of water that had accumulated in it was measured on the next visit. The results showed that a permanent water-table occurred at 17 feet depth during the whole of the wet season of 1946. The water level in borings to this depth rose rapidly to within 4 or 5 feet of the bed crest but it rose only slowly up to the same level in holes bored to lesser depths than 17 feet. From these observations it is concluded that, during the greater part of the wet season, free water occupied the cracks in the clay soil which it completely fills to within 4 or 5 feet of the bed crest. Drainage in rainy weather occurs laterally through the cracks in the bed to the drain sides. The bottom of the drain is about 36 ins. below the level of the bed crest.

Conclusions: It is evident from these considerations that the chief cause of waterlogging in the surface soils under consideration is impeded drainage in the deep subsoil. Except when their surface

* Within the past seventeen years at the College, 13 rainstorms of intensity greater than 2 ins. an hour have been recorded. The heaviest was 3.3 ins. an hour on 7th Sept., 1935. Six of these rainstorms occurred in the month of July.

† By contrast, the organic matter content of the Princes Town Clay Rendzina, a highly productive sugar-cane soil occurring in the Naparima District of South Trinidad, is about 4.0 per cent., with carbon-nitrogen ratio 12.0 and depth of organic layer, 12 to 18 ins.

exhibits low infiltrability through puddling or crusting, the permeability of these soils to water (at least down to the 2-foot depth) is very high, mainly because of the development of abundant cracks in them, particularly in the clays. For this reason, and provided the weather is not too continuously rainy, the soils are capable of absorbing and retaining large amounts of rainfall in their upper 2-foot layers where the cracks mostly occur. Hence, if they have dried out thoroughly in the dry season, they appear to be able fully to cope with normal wet season rains without the need of deep artificial drains. Considerable drainage appears to proceed in the cane beds laterally through cracks which open into the drain sides, being continuous with the deeper vertical cracks in the soil-mass. So long as the system of soil cracks continues to function, even if only intermittently, and does not fail because of permanent closure, there seems to be no reason why serious waterlogging should occur, except quite temporarily during excessively wet spells. Hence run-off should seldom occur and soil erosion should be reduced to a minimum. In actual fact, however, temporary closure of the cracks and soil puddling during long or intense rainy spells appear to induce run-off in these soils because of the instability of their surface structure. The chief danger to the crop seems to lie in extreme desiccation through continued drought in the dry season or during the "Indian summer" (September–October), and this is greatly enhanced by deep cracking.

(IV) Seasonal Variation in Effective Rainfall in Relation to Soil Moisture

(1) *Data for* 1927–28

In a previous article on the evaluation of soil moisture, a method devised by Dr. H. M. Leake for computing "effective rainfall" from daily rainfall records was applied to actual data for "available soil moisture" obtained at the College Farm.*

The method, suitably modified to exclude "torrential rain" (supposed to run-off the land), as well as the excess of rain-water above that required to saturate the soil layer in question, was found "to furnish a fairly reliable measure of available moisture, at least for uncropped sandy soil". The method accordingly has now been applied to the rainfall data for the years 1927-1928 for which weekly available soil moisture contents have been recorded for the top and second foot layers of soil comprising the sandy and the clayey plots in Field F 88, Caroni Estate, as described in Part I, Section IV of this article.

Unfortunately the correction for torrential rainfall could not be applied to these data, since no recording rain gauge had been installed in those early years. It is unnecessary to tabulate the relevant data in this place; instead, the results have been plotted in a diagram (Fig. 1), in which soil moisture contents for the two layers combined are expressed as inches of rain water which allows easy comparison with effective rainfall values.

FIG. 1

Discussion: The graphs in Fig. 1 exhibit similar features as those in Fig. 2 of Part 1 of this article which depicts in block diagrams the fluctuations of moisture and air in the same two kinds of soil for the same period of time. The year 1927 was characterised by having a wet dry season and a normal wet season, whereas 1928 had a dry dry season and a dry wet season. The graphs for effective rainfall for both years show greater fluctuations than those for actual available soil moisture, indicating that Leake's method under-estimates soil moisture during dry weather and over-estimates it during wet weather.† These tendencies have already been noted for the College Farm data.

* The Evaluation of Soil Moisture, F. Hardy, *Trop. Agriculture*, Trin. 1946, XXIII. Pp. 66-75.

NOTE: (1) The term *"effective rainfall"*, as used in this and the previous article, is rain that penetrates into the soil and percolates downwards and is absorbed into the rooting zone. Experimental evidence indicates that penetrating and percolating rain consists of medium showers having intensity between 0.74 and 0.41 ins. per hour. Torrential showers, having intensity 0.75 ins. per hour or more are wholely or partly "effective" only when the soil is dry and cracked or otherwise highly receptive or infiltrable. They are "ineffective" when the soil is already saturated with water, or when its surface is compacted, puddled or crusted. Light showers, that is, showers having intensity 0.40 ins. an hour or less, are "ineffective" because they evaporate without penetrating appreciably into the soil. Effective rainfall may thus be evaluated as the difference between total rainfall and the sum of the fractions which evaporate, run away and penetrate deeply beyond the rooting zone.

(2) *"Effective rainfall" as defined by H. M. Leake* is evaluated as the difference between total rainfall and the sum of the fractions which evaporate, run away and penetrate deeply, *together with* those which are removed by transpiration and fixed as "unfree" water by soil colloids. Leake's definition therefore applies to land carrying a crop and not solely to fallow land.

(3) *"Effective soil moisture"*, as used in this and the previous article, is synonymous with "gross soil moisture content". It includes transpired water when the land is carrying a crop, because this is physiologically effective in plant growth. It is not the same as *"available soil moisture"*, since a considerable proportion of the colloidally-held or "unfree" water cannot be abstracted by plant-roots, namely, moisture below the wilting coefficient level. Thus available soil moisture is derived from gross soil moisture by substracting the wilting coefficient value and it therefore approximately coincides with Leake's "effective rainfall".

† The detailed tabulations (not here recorded) showed that, for the *sandy soil*, available soil moisture exceeded effective rainfall by an average of about 1.1 ins. of rain during dry weather but gave an average deficit below saturation of only 0.5 ins. during wet weather. For the *clayey soil*, available soil moisture approximately equalled effective rainfall during dry weather but showed an average deficit of nearly one inch during wet weather. The net difference for the whole 2-year period for both soils combined averaged about 0.25 ins. in favour of available soil moisture content for each sampling occasion.

During the normal wet season of 1927, the effective rainfall values often greatly exceeded the theoretical saturation values for the two soils; the excesses are shown in the diagram by dotted lines. During the dry season of that year, saturation was scarcely reached by the effective rainfall line nor actually at any time by the available moisture content of the 2-foot layer as a whole. Presumably, however, had moisture contents been determined for a thicker layer (say 3 feet), and had a correction been made for torrential rain, the graphs for available soil moisture might more nearly have coincided with the effective rainfall line.

Conclusion: It is evident that the "effective rainfall" line furnishes a useful practical means of following the general trends of soil moisture content within the rooting zone of an average loamy soil.

Depth of moisture penetration: Effective rainfall graphs may be used for the purpose of roughly gauging the depth to which rain water will penetrate into a porous soil of known saturation capacity. Reference to Table III (soil constants) shows that 6.8 ins. of rain will saturate a 2-foot layer of the sandy soil and 5.4 ins. will saturate a 2-foot layer of the clayey soil already at wilting point, provided the wetting is uniform and that the water-front is sharp and not diffuse as it is in actual fact. From these data, the approximate depth to which the soil will be saturated by any given quantity of rain may be deduced. For example, in Fig. 1, the depths of penetration corresponding to different unit amounts of effective rainfall are given on the right hand side of the graphs. The data indicate that, for the sandy soil, the greatest amount of effective rainfall (reached on June 21st, 1927) would have penetrated roughly to 34 ins., and for the clayey soil, to 40 ins., which therefore mark the maximum depths of penetration for 1927, on the assumption made.

(2) *Data for* 1946

A check was made during the wet season of 1946 on the findings for 1927-28 by measuring at fortnightly intervals the moisture contents of each successive 6-inch profile layer down to six feet, and in some instances down to 13 feet, in sandy soil and clayey soil occurring at the same sites in Field 88 F, Caroni Estate, as before. A large extensible screw auger was used for collecting the deeper soil samples.

The results obtained are set out in part in Table IV and plotted in Fig. 2 together with effective rainfall data calculated by Leake's method applied to daily rainfall records both with and without correction for torrential rainfalls.

Discussion: The data for the sandy and the clayey soils are plotted separately. On each set of graphs, the depth of the successive layers corresponding with the number of inches of rain-water required in theory to saturate the soil, starting from wilting point (zero line), are given on the right hand side of the diagrams; their computation is based on the magnitudes of the soil constants set out in Table III. The levels for field capacity and saturation capacity for the uppermost 2-foot layer are specially indicated by horizontal lines drawn across the diagrams. The wet season of 1946 set in very sharply on the first day in May. The subsequent march of events is summarised below for the sandy soil and the clayey soil considered separately.

(A) *Sandy soil*: The moisture content was practically at wilting point when the rains came. The soil rapidly filled up with water from the surface downwards during the early rainy weather. At the peak of the rains at the end of June, the soil was nearly saturated to the 12-ins. depth and progressively drier below (Table IV) down to the water-table level which, at that time, lay at the 60-ins. depth. Judging by the position of the effective rainfall line, the soil should then have been saturated almost to the 36 ins. depth, whereas in actual fact, the amount of available water present in the top 36 ins. layer was only sufficient to saturate the soil down to the 29 ins. depth. Thus, as usual, effective rainfall greatly over-estimated the available moisture content during the wet season, particularly on this occasion when its onset was rapid. The positions of the available moisture lines for layers of soil of increasing 6-ins. depths (Fig. 2) are regular and evenly arranged. They begin to run nearly parallel to the effective rainfall line after September when the weather was less rainy. The available moisture line for the top 2-foot layer then nearly coincided with the effective rainfall line during October, November and December. It is concluded from these records that the sandy soil behaves normally like any single-grain porous medium offering only slight resistance to water penetration.

(B) *Clayey soil*: This soil also contained very little available moisture at the beginning of the 1946 wet season. It filled up rather slowly as compared with the sandy soil during the excessively rainy first half of May. At the peak of the rainy weather (end of June), the soil was saturated down to the 12-ins. depth, just as in the case of the sand (Fig. 2). The actual amounts of available moisture in the successive 6-inch layers below the 12-inch depth, were insufficient, however, to saturate the soil during this wettest period.

There is thus a marked lag between the available moisture lines and the corresponding depths to which the soil, in theory, should have been saturated, according to the figures set out at the right-hand side of the diagram. Thus, for example, the mean available moisture content of the 0–36 ins. layer of clayey soil on 2nd July was equal to that which theoretically should have completely saturated this layer down to the 30 ins. depth, whilst that of the 0–72 ins. layer was only equal to the amount of

TABLE IV

LIMITS OF AVAILABLE SOIL MOISTURE CONTENTS DURING WET SEASON OF 1946

(Data expressed as *inches of rain*)

	WETTEST PERIOD (June-July)				DRIEST PERIOD (Sept.)			
	SANDY SOIL		CLAYEY SOIL		SANDY SOIL		CLAYEY SOIL	
Profile layer (ins.)	Avail. moisture content	Saturation deficit	Avail. moisture content	Saturation deficit	Avail. moisture content	Saturation deficit	Avail. moisture content	Saturation deficit
0-6	1.63	0.07	1.25	0.10	0.71	0.99	0.19	1.16
6-12	1.41	0.29	1.41	0.00	0.95	0.75	0.54	0.81
12-18	1.23	0.47	1.21	0.14	0.93	0.77	0.47	0.88
18-24	1.19	0.51	1.13	0.22	1.03	0.67	0.53	0.82
24-30	1.29	0.41	0.93	0.42	0.88	0.82	0.91	0.44
30-36	1.29	0.41	0.88	0.47	0.88	0.82	0.92	0.43
36-42	1.19	0.51	0.60	0.75	1.06	0.64	0.77	0.58
42-48	1.10	0.60	0.29	1.06	1.13	0.57	0.63	0.72
48-54	1.36	0.34	0.34	1.01	1.18	0.52	0.27	1.08
54-60	1.43	0.27	0.65	0.70	water-table at 4½ ft.		0.54	0.81
60-66	water-table at 5 ft.		0.50	0.85			0.44	0.91
66-72			0.50	0.85			0.60	0.75
72-78	clay substratum below 6 feet		0.69	0.66	clay substratum below 6 feet		0.87	0.48
78-84			0.93	0.42			0.23	1.12
					132 ins.,		0.80	0.55

Available moisture per 6 ins. layer	*Sandy soil*	*clayey soil*
Saturation capacity ...	... 1.70 ins.	1.35 ins.
Aeration lower limit ...	... 1.10	0.75
Field capacity	... 0.60	1.12

water required to saturate this layer down to 43 ins. (Fig. 2). The existence of this lag (not shown so markedly by the sandy soil) implies that the clayey soil loses much of the incident rain water through deep fissures and cracks. As in the case of the sandy soil, effective rainfall during the early rainy period greatly over-estimated the available moisture content of the clay, although later it approached closely to the available moisture line for the 2-foot layer, as indicated in Fig. 2.

Differences in the behaviour of sandy and clayey soils :

Apart from the different drainage features of the two kinds of soil (the sand showing a definite water-table during wet weather at about the 60 ins. depth and the clay possessing deep cracks which drain off a considerable amount of water both vertically and laterally), the clayey soil dries out much more rapidly when rainy spells become infrequent. This is shown by the graphs in Fig. 2 and by the available moisture values for the driest period of the 1946 wet season set out in Table IV. These values are much less in magnitude for the upper 2-foot layer of clayey soil as compared with the sandy soil, a result which may again be attributed to the effect of cracks. Repeated pit inspection in the clay plot showed that cracks persist throughout the rainy season, opening and closing along the same axes as the weather changes.

The amount of soil moisture available to cane-plants growing both in the sandy and in the clayey soils during the second half of the wet season of 1946 was relatively small, judging by the data in Table IV which represent the conditions in late September, 1946. This month, mostly comprising the Petit Careme or Indian Summer, was somewhat drier than usual (total rainfall for the month, 6.7 ins.; 20 years' average 8.8 ins.). There was a saturation deficit in the top 2-foot layer of 47 per

cent. of the saturation capacity in the sandy soil and 68 per cent. of saturation in the clayey soil. Whereas the moisture content was then just outside the capillary (field capacity) range for the sand, it was well inside it for the clay. It is considered that these values denote an inadequate water-supply, and it is therefore concluded that there may be real danger of water-shortage during a large part of the wet season at Caroni Estate.

Conclusion: The data for 1946 substantiate those of previous investigations of the same sandy and clayey soils; they demonstrate the influence on the moisture relations of clay soils of deep and persistent cracks which not only provide avenues for vertical and lateral water-movement, but also allow of the rapid removal of water by drying out between rainy spells.

(V) Variation in the Features of Effective Rainfall Graphs for Different Years

It has been shown that considerable deviation is likely to occur between graphs depicting the calculated effective rainfall derived by Leake's method from daily rainfall readings and graphs showing the actual available moisture content of the upper layer of soils having extremes of texture. Nevertheless, the evidence so far obtained indicates that the general moisture conditions in an average soil are followed sufficiently closely by the effective rainfall line to warrant its use for depicting differences in soil moisture conditions in different years. Thus, at Caroni Estate, the rainfall regimes for various years have shown considerable deviation and no two years' rainfall possess the same features. This is strikingly shown by the "silhouette" diagrams in Fig. 3 where the effective rainfalls (not corrected for torrential showers) for certain selected years are brought together for comparison. The effective rainfall diagrams are inverted so as to indicate the theoretical depths to which water penetrates in sandy and clayey soils similar to those occurring in Field F 88.

The selected years, with their chief rainfall characteristics, are all included in Table I; they are 1938, 1927, and 1944, representing wet years, 1940, a medium year, and 1928 and 1934, representing relatively dry years. The difference in annual rainfall between the extreme years, 1938 and 1934, is 37.3 ins.. The main features which characterise a dry year at Caroni apparently are 4 to 5 dry months having average rainfall only just over one inch and 7 or 8 wet months having average rainfall about 8 ins. By contrast, a wet year at Caroni has only about 3 dry months with average rainfall 1.5 ins., and 8 wet months with average rainfall of nearly 11 ins. The main difference between the yearly rainfall regimes, however, lies in the monthly distribution of the rain, as the effective rainfall "silhouette" diagrams clearly indicate.

(VI) Yields of Sugar-Cane in Relation to Effective Rainfall

In his article "Rainfall and Crop Conditions",* Leake adduced a regression equation connecting yield of sugar-cane, in tons per acre, of a typical sugar-estate in Barbados with the average daily effective rainfalls in tenths of an inch for (1) the wet season prior to planting (p), (2) the dry season following planting (d), (3) the wet season in which most of the plant growth (g) occurs. The equation is :—

$$\text{Yield} = 0.026\,p + 0.055\,d + 0.540\,g + 4.12.$$

This equation has been applied to the Caroni effective rainfall data for the selected years indicated in the last section. The results obtained are set out in Table V.

* *Trop. Agriculture, Trin.*, 1929, Vol. VI, Pp. 43-45 .

TABLE V

HYPOTHETICAL YIELDS OF SUGAR-CANE CALCULATED FROM LEAKE'S REGRESSION EQUATION

(Rainfall expressed as *tenths* of an inch)

Year	Total rainfall (ins.)	Average effective rainfall: Value for p (wet season prior to planting)		Value for d (dry season following planting)		Value for g (season of most growth)		Sum	Tons cane per acre: plus 4.12	Actual yields supplied by the management
		(p)	0.026p	(d)	0.055d	(g)	0.54g			
Wet years										
1938	96.9	38.3	1.00	28.0	1.54	68.6	37.04	39.58	43.7	60.6 (Plants)
1927	95.0	No daily rainfalls recorded						—	—	17.8 (2nd rats.)
1944	87.9	50.0	1.30	12.9	0.71	71.1	38.39	40.40	44.5	25.8 (plants)
Intermediate										
1940	79.5	59.4	1.54	17.0	0.93	62.4	33.70	36.17	40.3	24. 6 (plants)
Dry years										
1928	60.8	59.7	1.55	15.7	0.86	45.7	24.66	27.07	31.2	28.4 (plants)
1934	59.6	70.3	1.83	12.3	0.67	47.1	25.43	27.93	32.0	

Leake's calculations of Barbados cane-yields for the years 1911-1926 inclusive show that it is "possible to estimate at the end of December, and consequently before the commencement of cutting the crop, the probable yield with an even chance of being within 3 tons of the actual". Unfortunately, it is hardly possible fully to test the data given in Table V for Caroni Estate, since many of the years presented abnormal conditions with respects to labour supply. The last column of Table V contains actual yield data for Field F 88 supplied by the Manager of Frederick Section of Caroni Estate. The yields for plant-canes grown in the years 1938 (wet), 1944 (wet), 1940 (intermediate) and 1928 (dry) are erratic and do not conform with the values calculated from Leake's formula. It may be conceded, however, that the years 1944 and 1940, being abnormal war years, could not be expected to produce yields commensurate with the relatively high rainfalls actually experienced in those years.

Summary and General Conclusions

(1) In this second part of an article on water and air relations of sandy and clayey sugar-cane soils, the characteristics of the rainfall over the area where they were investigated (Caroni Estate, North Trinidad) are first described, based on recording rain-gauge data collected during the past 20 years, at the College nearby. The variation in total annual rainfall was roughly 78 + 24 ins. The number of "dry" months (rainfall below 2.4 ins.) varied between 6 and one, and of "wet" months (rainfall above 4.0 ins.) between 6 and 11, according to Mohr's standards.

(2) Estimates of the amount of evaporation indicate that 60 per cent. of the total annual rainfall is lost from this cause, leaving 40 per cent., or an average of 31 ins., for penetration and run-off; i.e. 4 ins. per month in a wet season of eight months' duration.

(3) Analyses of rain showers show that "soaking" or "effective" showers fall on the average, in the wet season, only once in three and a half days and each lasts on the average only 39 minutes.

(4) Soil moisture constants were measured so that calculations could be made of the theoretical depths of penetration of soaking rains into sandy soil and clayey soil, or alternatively, of the amounts of rain required to raise the soil moisture status in layers of arbitrary depth from wilting level to field capacity and to saturation capacity. The results indicate that, for evenly-spaced showers, saturation and run-off are seldom likely to occur, *provided surface soil structure is unimpaired* and infiltrability remains at a high value. In actual practice, crack closure and surface puddling during periods of long-continued or intense rainfall may greatly reduce infiltration, so that run-off and erosion may occur over the highly cambered beds.

(5) Available soil moisture data for sandy and clayey soils, collected weekly during 1927 and 1928 for the top and second foot layers, and fortnightly during 1946 for successive six-inch layers to six feet, were compared with total effective rainfall calculated by Leake's method from daily records kept at the College, and with effective rainfall corrected for torrential showers. The comparisons showed considerable discrepancies, but it is suggested that "effective rainfall" graphs give a sufficiently exact picture of the moisture conditions in the soil to warrant their use for comparing annual rainfall regimes. This is illustrated by reference to typical wet, intermediate and dry years at Caroni.

(6) By inverting the effective rainfall diagrams, some idea of the theoretical depth of penetration of rain water may be obtained. Actual soil moisture data determined in the wet season of 1946 showed, however, that the effective rainfall graph exaggerates penetration when the rainy season sets in suddenly and intensely, but coincides fairly closely with the available moisture content of the top 2-foot layer of soil during normal wet-season rains.

(7) Leake's formula for calculating sugar-cane yields from effective rainfall values, applied to the data for typical wet, intermediate and dry years at Caroni, shows a range of theoretical yields between 44 tons per acre for the wettest year (1938) and 32 tons per acre for the driest (1934). These results only approximately coincide with actual yield data, though these are unreliable however, because of irregularities caused by labour shortage during the War.

(8) It appears likely from these investigations that wet years at Caroni Estate are more conducive to high yields of sugar-cane than dry years, and that there may be a real danger of over-draining the soil by constructing beds that are too narrow and too highly cambered. One of the main objects of tillage should be to induce rain-water to enter the soil and so to become "effective" in producing a crop, rather than to permit it to run off the land and so to cause erosion and loss of fertile surface soil.

Explanation of the Diagrams

FIG. 1

This diagram includes (1) a record of the tri-daily rainfalls (inches) represented by vertical columns ("chimney stacks") at the foot of the diagram, (2) a graph of the mean monthly (30-day) rainfall, expressed as a moving average based on the tri-daily values, and (3) a graph of "effective rainfall", calculated by Leake's method from the daily rainfall figures. The rainfall data include showers of all categories; torrential showers have *not* been discarded.

COMPARISON OF AVAILABLE SOIL MOISTURE DIRECTLY DETERMINED WITH EFFECTIVE RAINFALL CALCULATED BY LEAKE'S FORMULA

DATA FOR PLOT SOILS (SANDY AND CLAYEY) FIELD F88, CARONI SUGAR ESTATE, TRINIDAD

FIGURE 1

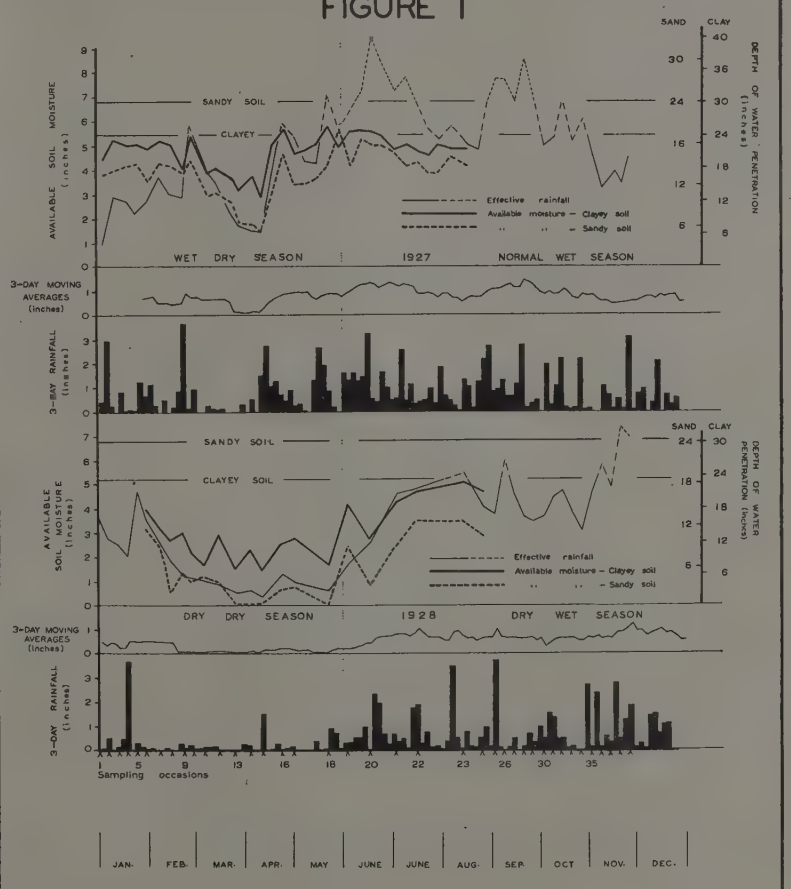


FIGURE 2

COMPARATIVE DATA FOR 1946
(SANDY AND CLAYEY SOILS)

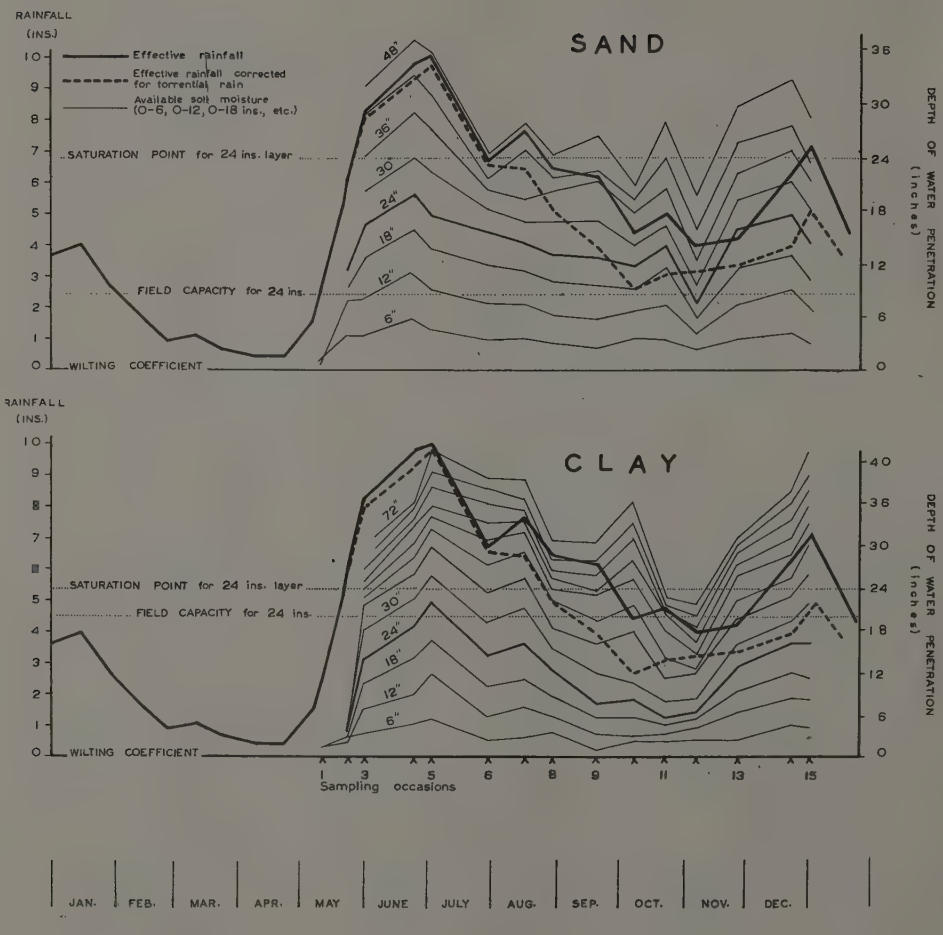
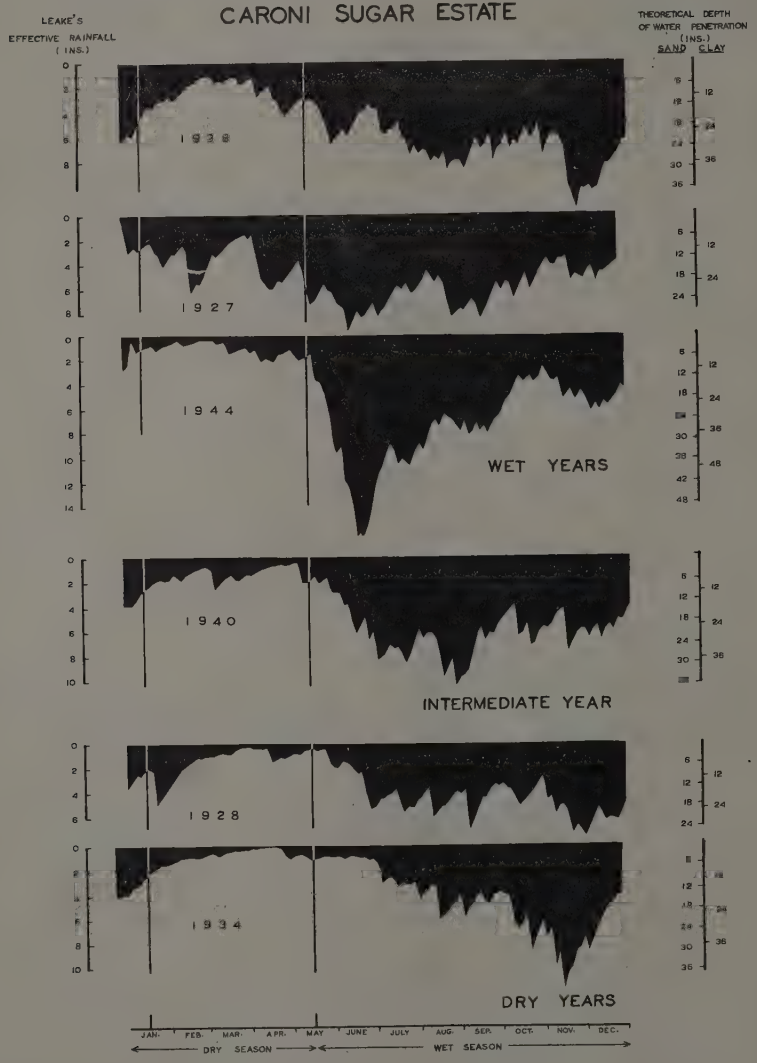


FIGURE 3

VARIABILITY OF EFFECTIVE RAINFALL

CARONI SUGAR ESTATE



The available soil moisture contents are expressed as inches of rain water so as to allow easy comparison with effective rainfall values.

FIG. 2

Each set of graphs gives (1) the "effective rainfall" for 1946 calculated by Leake's method with (broken heavy line) and without (solid heavy line) correction for torrential showers; (2) the available soil moisture content of increasing 6-ins. depths (i.e. 0-6 ins.; 0-12 ins.....0-48 ins., &c.) expressed as inches of rain water. The levels for field capacity and saturation capacity for the uppermost 2-foot layer are indicated by horizontal dotted lines drawn across the diagrams.

FIG. 3

"Silhouette" diagrams showing effective rainfalls (not corrected for torrential showers) for selected years inverted so as to indicate the theoretical depths to which water penetrates in sandy and clayey soils similar to those occurring in Field F. 88. The depth of penetration is indicated at the right-hand side of the diagram.

CANE-FARMING IN BRITISH GUIANA

BY

ST. G. C. COOPER, A.I.C.T.A., Dip. Agric. AND E. G. B. JONES, Dip. Agric.

Introduction

In the British Guiana sugar industry, the term "cane-farming" refers specifically to the cultivation of cane by small farmers on relatively small units of production. The manufacturing processes are confined to large factories owned by joint stock companies which mill the canes of these small farmers. The large plantations cultivate and mill their own canes.

The early history of cane-farming lies in a scattered literature, but it is known that it dates back to the years immediately following the abolition of slavery. Cane-farming constitutes 2 per cent. of the Colony's output of sugar with approximately 87 per cent. of the farmers contributing below 50 tons of cane each and only 13 per cent. contributing 50 tons and over. The industry is by no means evenly distributed over the sugar belt, and while it is of limited importance in the Colony's economy, it is a major source of income in the areas where it is centred. The peculiar features of the industry are perhaps not duplicated elsewhere in the sugar world, and it may be of general interest to describe briefly the background and general conditions under which cane-farming is carried out.

General

The production of cane sugar is the most important industry of British Guiana, the value of sugar and its by-products constituting about 70 per cent. of the total normal value of the Colony's exports. Cooper (1937), and Williams and Follett-Smith (1944) have recently described the conditions under which sugar cane is cultivated in British Guiana and it may be useful to summarize that part of their paper dealing with general conditions.

The whole of the British Guiana sugar is produced within eight miles of the sea on rectangular estates that have either the ocean or the tidal reaches of a river on one side of their rectangle. The land is flat, below or barely above sea level and is protected by dykes; provision has to be made to get excess rainfall out of the empoldered area. Each field is surrounded on three sides by high level irrigation canals and on the fourth by a low level drainage canal to which the internal drainage of each field is connected.

The mean annual rainfall varies between 72 and 106 inches. The two main soil types under cane are the frontland clay and the pegasse soil. The frontland clay forms about 75 per cent. of the land under cane cultivation and consists of an acid top soil containing some soluble salts, overlying a stiff heavy clay increasing in alkalinity and salinity with depth; below 12 inches the salinity is usually harmful to cane growth. For the greater part of the year, these soils are either too dry or too wet to work. The pegasse soil type consists of a layer of highly acidic peat overlying a heavy clay which increases in acidity with depth, but contains practically no soluble salts.

Thus, it will be seen that the physical features of the littoral of British Guiana, and the high capital and overhead charges of sea defences, irrigation and drainage demand an efficient and intensive form of farming such as is required in few, if any, of the British tropical dependencies.

It is against this background that the cane-farming industry must be considered, for it is obvious that in order to reach a high standard of cane cultivation small farmers must transform their individual efforts into co-operative action.

Some Aspects of the Industry

Cane-farming is limited at present to four villages on the East Coast of Demerara and to two areas in the County of Berbice. It is of considerable economic importance in the life of the villages concerned, for the sale of cane is a prime source of revenue for over two thousand farmers and their families.

Cultural practice is of a low standard and is probably influenced to a certain extent by the peculiar system of land tenure. When slavery was abolished,

the freed men found it expedient to unite in groups and purchase certain abandoned plantations on which the capital expenditure of bringing into cultivation (or empoldering) had already been met. These freed men settled in communities not on separate farms—and subsequently farmers of other races joined the communities. Thus was evolved the village communities which inhabit the coastlands to-day. But the basis of allotment in these villages was equality between the owners, with due regard both to soil type and the area of land secured by each proprietor in each block or section of the plantation. Later, second and extra depths of land were bestowed on the villages under various forms of Crown grants and were themselves divided up into as many strips as there were original proprietors. The system exists to the present day and inflicts certain evident disadvantages, for the farmers remain settled, not individually on their several farms, but communally in villages with a fragmentation of holdings, which are frequently at considerable distances from each other and from the home of the farmer.

The system affects adversely the drainage of the cane farmer's holding which is of supreme importance in the agricultural system of British Guiana. "B" for example may wish to drain his bed but unless "A" and "C" who own adjacent beds on either side are willing to co-operate he is forced to dig the drains entirely on his own land. The digging of drains calls for much time and labour and when dug, they also drain the adjoining beds. Since the space occupied by the two drains considerably reduces the area of the bed left for planting, it is obviously unfair for "B" to be forced to dig both drains on his bed. Thus the maintenance of drainage operations can be met only by communal and not individual action.

The interpolation of rice beds between the cane beds is another evil resulting from the present distribution of land.

The yields obtained compare very unfavourably with those reached on the estates, and it seems that the difference must be attributed to (i) failure to flood-fallow (a system of soil renovation peculiar to the cane-lands of Guiana and which consists in the total submergence of cane fields under water for periods varying from three months to two years), (ii) failure to keep a sufficient proportion of plant canes, (iii) failure to change over to the best varieties sufficiently rapidly, (iv) failure to use pen manure and adequate quantities of nitrogenous fertilizer, (v) inefficient drainage, and insufficient tillage, and (vi) the presence, in some instances, of fruit trees and ground provisions between the cane.

Not until late in 1945, had the main cane-farming areas been flood-fallowed, a practice which the sugar estates for long years have found essential for the maintenance of fertility.

Flood-fallowing, however, has been impracticable for small cane farmers owing to the absence of the large continuous blocks which are necessary and which could only be effected by communal action in the industry.

In the Berbice Group, there is one cane-farming area, Plantation Lochaber, with an acreage of approximately 480 acres. This is the only instance of any attempt at large scale cane production other than by the joint stock companies.

Cane cultivation at this plantation is of a much higher standard than that carried on by the small cane farmer either in Berbice or in East Demerara. Lochaber has been flood-fallowing, using adequate quantities of fertilizers for a number of years, and has been planting the newer varieties of cane more rapidly than other cane farming areas.

Apart from Plantation Lochaber there is no farmer cultivating more than 25 acres of cane. Even the farmers who cultivate between 20 and 25 acres of cane have their cane-beds not in a continuous block but scattered over the whole village area.

Village Conditions

Giglioli has calculated that in one square mile of cane cultivation in British Guiana, laid out in ten-acre fields, there are:—

16 miles of high level canals
4·5 „ „ low „ „
45 „ „ drains

These huge exposed water surfaces provide breeding grounds for mosquitoes and prevent farmers from residing on their holdings. Indeed, the same topographical conditions led the original purchasers of the estate (who as slaves were used to dwelling in barracks), to build their houses together in village communities on the windward section of the estate. Thus, a formidable difficulty in the fight against malaria is that ordinary drainage measures cannot be applied as is done in other places. The two main agricultural industries depend entirely on irrigation, and according to Giglioli, "without the huge net-work of anopheles-producing canals and rice fields, those industries would be unable to carry on".

The villages emerged from a system where the necessary maintenance works were done co-operatively under the direction of elders to a system of local government, whereby they are administered by a Council composed mainly by election. The Council is responsible for the maintenance of the residential and cultivated areas and for the provision of amenities such as markets, roads, etc.

The road and rail system, connect village to village, the former usually following the sand reefs near the sea shore. The roads only run in the residential area and there are no feeder roads running the whole length of the villages. All transport in the cultivated areas is by water.

Cane and Sugar Production

Table I shows for the period 1932 to 1945, the approximate acreage under cultivation, the acreage reaped, tons cane and tons sugar produced, and the average yield per acre of farmers' canes as compared with the average estates' yield in the same districts.

Scrutiny of Table I reveals that the trend of production was upwards until the industry received its first major set back with a disastrous drought in 1939. The effect of this was a considerable reduction of acreage in 1940 which was partly offset by a marked increase in the yield of cane per acre. In connection with this last phenomenon, it may be mentioned that it has been noticed in this Colony that following a severe drought, yields even of rice, tend to rise considerably. It is generally assumed that this is the result of the thorough drying out of soils which are, in general, very poorly drained.

Following on the year 1940, there was a slow but steady expansion in acreage with moderate yields of cane per acre. In 1942 however, disastrous floods occurred throughout the Colony and the effect in the subsequent year, as was to be expected, was a marked decline in the acreage under cultivation as well as a sharp drop in the yield per acre. Were it not for an improvement in the price per ton of cane, the industry might not have been able to survive the shock. In the year of writing, there has been a keen revival of interest in cane-farming, which may be attributed to better prices, proposals for flood-fallowing farmers' canes and the desire among farmers themselves for the extension of new varieties approved by the Department of Agriculture.

The yield per acre is approximately half that obtained on the neighbouring sugar estates, but this is not unexpected in view of the lack of flood-fallowing and the deficient drainage obtaining.

Official Efforts at Improvement

In 1930, the Director of Agriculture proposed that a preliminary enquiry into the industry should be made, and Williams and Peterkin, who conducted the enquiry, made certain recommendations as to fertilizers, toll charges, communal pumps for irrigation, re-distribution of village lands and the general re-organisation of cane-farming. Some of these recommendations were implemented, and a Committee known as the Central Cane Farmers' Committee was established to deal with all matters pertaining to the welfare of the cane-farming industry.

A fillip was given to the industry as a result of these recommendations and the interest taken by the sugar estate authorities, as well as a revised agreement between the cane farmers and the Sugar Producers' Association guaranteeing a minimum price of $2.20 per ton of canes.

Cane-farming enjoyed a period of moderate prosperity until recent years when, in view of recurrent floods, the high price and scarcity of fertilizer, and the steep rise in the cost of hired

TABLE I.

STATISTICS OF FARMERS' CANE AND SUGAR PRODUCTION ETC.

Year	Acreage under Cultivation	Acreage Reaped	Tons Cane	Tons Sugar	Average Yield Per Acre (3-crop cycle) Sugar Estates 1932-1945	Average Yield Per Acre (3-crop cycle) Farmers' Canes 1932-1945
1932 ...	1,325	Not available	24,564	2,047	35 tons cane per acre	18 tons cane per acre
1933 ...	1,525	,,	27,936	2,328		
1934 ...	1,772	,,	25,464	2,122		
1935 ...	2,207	,,	40,128	3,344		
1936 ...	2,711	1,964	49,380	4,115		
1937 ...	2,678	1,984	49,344	4,112		
1938 ...	2,664	1,997	50,916	4,243		
1939 ...	2,506	1,621	41,748	3,479		
1940 ...	1,497	1,347	36,103	2,876		
1941 ...	1,926	1,645	44,736	3,557		
1942 ...	2,005	1,777	46,262	3,843		
1943 ...	1,829	1,732	34,094	2,365		
1944 ...	1,400	1,648	26,024	2,336		
1945 ...	1,386	1,287	25,542	2,527		
1946 ...	1,873	1,542	36,345	3,316		

labour, the industry found itself in a precarious condition. Government in 1944, appointed a Cane-farming Officer whose functions, among other things, are to perform advisory work among cane farmers and to act as liaison officer between the factories and cane farmers. About the same time a further enquiry into the industry was made in order to determine (i) what assistance could be given to tide over the crisis and (ii) what improvements in the practice of cane growing by farmers could be effected with a view to raising the yield per acre.

Cooper and Jones, who conducted the enquiry found the basic needs to be (i) improved drainage and (ii) the conservation of soil fertility. After making some general recommendations, specific proposals for the flood-fallowing of farmers' canes were formulated and, in the light of these proposals, Government, with the approval of the Legislative Council, allocated $23,560 to be expended on the industry to assist in setting it on a proper footing. Thus, for the first time, it has been possible, in 1945 (after ironing out several practical difficulties) to flood-fallow farmers' land. It represents a revolution in the technique of cane cultivation by small farmers (by which, in the first year, it is proposed to flood-fallow 350 acres of their cane lands, and a quarter of the total acreage in subsequent years) and marks a new phase in the development of the industry as a whole.

Organization of Cane-Farming

Each cane-farming village has a Cane Farmers' Association which looks after the welfare of its individual members. These Associations are represented on the East Coast Central Cane Farmers' Committee by two members with the proviso that only representatives from not more than two associations in any one district shall be represented on that Committee. This Committee, though not a statutory body, is the only body recognised by the Sugar Producers' Association in negotiations with the farmers; and has as its Chairman, the District Commissioner, and as its Vice-Chairman, the District Agricultural Superintendent.

In addition to the Central Committee, there is a price fixing Committee which consists of two representatives, each of the Sugar Producers' Association, and the East Coast Central Cane Farmers' Committee, with the Agricultural Chemist as Chairman.

The estates keep records of the date of planting and cutting of farmers' canes. This information is collected by a cane farmers' field superintendent, who is also responsible for the distribution and allocation of punts (transportation is free) and the regulation of harvesting. With the appointment of a Cane Farming Officer, an index system of the entire cane farming areas has been started. This should act as a check on the data collected by the estates and tend to better control of the industry.

Advances, &c.

Two per cent. of the total fertilizer imports are generally allotted to cane farmers who purchase from the estates on credit. Interest at the rate of six per cent. is charged on the value of the manure. Payment is made at the end of the crop by deductions from cane sales.

The price of cane is generally fixed towards the end of the crop but in order to facilitate farmers, the estate agrees to advance payment at the rate of four dollars per ton of cane delivered. The balance of payment is made when the price is finally computed. By agreement between the Sugar Producers' Association and the cane farmers, two gallons of final molasses are given to each farmer for every ton of cane delivered. The farmer is allowed one or two weeks to take delivery of his molasses, but in some cases the estates may purchase it from him if it is not required to feed his stock. Under the same agreement, the farmer is allowed to purchase ten pounds of sugar at cost price.

Method of Payment for Farmers' Canes

In common with other cane-farming industries, there was, in the early beginnings of the industry, a series of disputes with respect to price, which had to be settled. At first, payment was made by gallon of juice according to polariscope test and paid for according to the market price of sugar. On some estates, instead of paying for the juice by the gallon, the canes were bought by the punt load. Difficulties arose in this respect, for estates complained that the punts were not properly loaded. A table prepared by Scard, formed the basis on which payment was then made. After some time this method was changed and canes purchased on the weight basis on an agreement between the Sugar Producers' Association and the cane farmers.

In 1939, the price paid for farmers' canes varied with the f.o.b. value of export sugar according to the following scale which was fixed in 1933 and which was based on the assumption that it required twelve tons of cane to make a ton of sugar :—

F.o.b. value of 100 lbs. Sugar	Price per ton of Farmers' Cane
$ 1.80	$ 2.20
1.90	2.30
2.00	2.47
2.10	2.62
2.20	2.76
2.30	2.91
2.40	3.00
2.50	3.17
2.60	3.34
2.70	3.50
2.80	3.69
2.90	3.86
3.00	4.03

In 1940 until the first half of 1943, there was, in addition to the prices paid according to the 1939 schedule, a bonus of 20¢ per ton cane paid for the varieties of P.O.J. 2878 and Diamond 10 " provided that the farmers guaranteed the delivery to the factories of clean cane, free from trash and tops, and properly cultivated. The estate reserved the right to refuse cane not in good condition or not properly ripe".

In the second half of 1943, a Committee appointed by Government to revise the position, recommended that the price of farmers' canes should be based (1) on the quality of the latter as determined by factory tests carried out by the Chemist attached to the Department of Agriculture and (2) on two-thirds of the value of unbagged sugar at the factory as determined at half-yearly intervals by a Cane Farmers Sugar Committee comprising a Government Officer as Chairman, two representatives of the British Guiana Sugar Producers' Association and two representatives of the cane farmers.

The method at present used for testing farmers' canes is based on the determination of the weight and composition of the mixed juice derived from a weighed parcel of cane of not less than fifty tons; from the data so obtained the yield of 96° sugar is calculated. The result of the test is expressed as the number of tons cane required to produce one ton 96° sugar.

In evaluating the net price of unbagged sugar at the factory, the value of special preference certificates is included but not that of the Canadian Benefit Pool. The loss on local sales of sugar is omitted from the calculation. The usual c.i.f and f.o.b. expenses are deducted as well as the cost of bagging.

In 1947, further deductions are—the levies for price stabilisation, rehabilitation reserve and labour welfare ($13.20 per ton), and the special levy on export sugar ($1.20 per ton).

The value of sugar from farmers' cane thus calculated for 1943-1947 is shown below; the actual price paid to farmers for their cane is obtained by dividing this value of sugar by the figure " tons cane per ton of sugar " as determined for the various groups of farmers by the Agricultural Chemist.

	Two-thirds of the value of Unbagged Sugar per ton	Prices paid for Cane
1943 Autumn	$ 37.23	$2.98 — $3.39
1944 Spring	40.32	3.25 — 3.88
1944 Autumn	41.49	3.47 — 4.11
1945 Spring	45.54	4.14 — 5.12
1945 Autumn	45.03	3.72 — 5.23
1946 Spring	52.15	3.83 — 5.22
1946 Autumn	52.45	4.16 — 5.04
1947 Spring	57.79	4.82 — 5.90

In comparing these cane prices with those paid in the West Indies, it must be remembered that British Guiana farmers' cane usually takes 12 or even more tons of cane to make a ton of sugar. The growth in economic importance of the industry, however, is shown by the fact that the value of the crop has risen from about fifty-one thousand dollars in 1932 to approximately one hundred and forty thousand dollars in 1946.

The question of payment for farmers' cane is inextricably bound up with the quality of their cane. The original basis on which their cane was purchased was 12 tons of cane per ton of sugar. Since 1936, typical figures for farmers' cane delivered at one factory have been as follows :—

1936	—	12.22 tons
1937	—	12.80 „
1938	—	13.02 „
1939	—	12.27 „
1940	—	13.70 „
1941	—	13.91 „
1942	—	14.21 „
1943	—	12.59 „
1944	—	10.73 „
1945	—	10 34 „
1946	—	10.80 „

Thus from 1936 to 1942 there was at this factory, a progressive deterioration in the quality of farmers' canes. This deterioration in quality has been in general associated with considerable quantities of tops and trash, harvesting of over-ripe cane, bad drainage and the use of inferior varieties. From 1943, however, when payment of canes was based on the juice test, there has been a progressive rise in quality which has probably been associated with the more careful harvesting of ripe canes only.

Discussion

In 1930, the Director of Agriculture in an Administration Report stated "One of the greatest problems the Colony is faced with at the present time is the economic settlement of the West Indian agricultural population and there is little hope of this being achieved successfully under existing local conditions, where the farmers live at a considerable distance from their farms, excepting through the medium of sugar cultivation. The Department considers that every effort should be made in this direction, notably on the East Coast of Demerara, where the population finds in sugar a crop to which it has long been accustomed, and since on the coastal clays (with the exception of rice) there is no other important money crop that can be grown".

Fifteen years have not diminished the wisdom of this statement and eleven years later Wakefield, Inspector-General of Agriculture, re-emphasised the same view. Data collected by Huggins in a study of the economics of the small farm also supports this view, for he found that successful farmers obtain thirty per cent. of their receipts from cane and forty-five per cent. from wages off the farm, generally on the sugar plantation. He further stated that this offered one explanation of the establishment of the most successful farming settlements of the Colony in the vicinity of sugar estates and the apparent decadence of farming in areas, where sugar plantations, once in existence, have gone out of operation.

Huggins' study revealed that of 531 farms studied 54 per cent. were of less than 2 acres, 34 per cent. of 2 to 4 acres, 8 per cent. of 4 to 6 acres and only 4 per cent. of 6 acres and over. He concluded that one of the factors making for success in the industry is a farm size of not less than 6 acres.

Like his counterpart in Trinidad, the Guiana farmer, particularly the West Indian, normally divides his time between cane growing and wages off the farm. The cultivation of food crops, rice production, and the keeping of livestock, are other enterprises in which some cane farmers engage. About one-third of the East Indian cane farmers keep livestock, mainly cattle; nearly two-thirds of the West Indians have livestock of one kind or another, including pigs. However, in spite of this distribution, one in every three East Indian farmers tends cows, while only one in twenty West Indian does. Practically all East Indian cane farmers cultivate rice, but extremely few West Indians do, the latter preferring the cultivation of food crops.

It is noteworthy that the Trinidad cane-farming industry has been developed with practically no assistance from Government. It is, however, clear from the conditions described, that the cane-farming industry of British Guiana cannot withstand the preliminary capital expenditure involved without outside aid. In 1933, for example, a scheme for widening the navigation trenches and constructing aqueducts to enable farmers in the smallest cane-farming village, to plant canes and transport them to the neighbouring factory, was completed at a cost of $11,000.

Of this sum, $7,500 was provided from Unemployment Relief Fund and $3,570 from a loan made to the village district.

In another district, an aqueduct was constructed by the Local Authority at a cost of $3,000 which was repaid in tolls—a charge of twenty cents being levied on each punt of cane. There are, of course, the annual charges for maintenance or operation which represent expenditure from which cane farmers in other countries are exempt.

Summary

1. The term "Cane-Farming" and the general condition of cane farmers' cultivations in British Guiana are described.

2. It is shown that the industry is one of limited importance in the Colony's economy, but of major importance in the life of the villages concerned.

3. Official efforts at improvement, culminating in the flood-fallowing of farmers' lands in 1945, are traced, and the organization of cane-farming is described.

4. It is shown that where conditions permit the pursuit of the industry, only co-operative and collective action by farmers can lead to a higher standard of progress, owing to the high capital and overhead charges of sea defences, irrigation and drainage.

Acknowledgment

This paper is really an attempt at compiling for easy reference the salient aspects of cane-farming in British Guiana, and the authors have drawn their information from the several sources cited and for which due acknowledgment is made.

The writers wish to thank the Director of Agriculture for permission to publish this paper and to express their gratitude to Mr. C. Holman B. Williams, Deputy Director and Mr. J. F. Williams, Consulting Chemist, for many valuable suggestions.

References

Cooper, St. G. C. 1937, Cane Growth Studies in British Guiana, *Agric. Jour. British Guiana*, Vol. 8, 1937.

Williams, C. H. B. and Follett-Smith, R. R. 1944, Sugar Agronomy in British Guiana, *Proc. Meetg. Sug. Tech. B.W.I.* p. 96, 97.

Giglioli, G. 1938, Malaria in British Guiana, *Agri. Journal of British Guiana*, Vol. 9, p. 201.

Administration Reports 1930-1945, Director of Agriculture, British Guiana.

Williams, C. H. B. and Peterkin, E. M. 1930, Report on the Cane Farming Industry, British Guiana.

Cooper, St. G. C. and Jones, E. G. B. 1944, Report on the East Demerara Cane Farming Industry with suggestions for its improvement.

Howell, Jones B. 1906, Cane Farming in British Guiana—*Colonial Reports Miscellaneous*, West Indies, No. 36, p. 61.

Huggins, H. D. 1937, An Economic Survey of Farming in East Demerara, *Agric. Journal, of British Guiana*, Vol. 8, No. 3. Pp. 6.

District Commissioner's Report. 1933, East Coast Demerara District.

THE HOLE PLANTING SYSTEM OF THE UPPER AMAZON VALLEY

In this system, of unknown origin, which is used for nearly all plants grown in this area, *e.g.* coca, cube, cinchona, tea, citrus, etc., holes from 12 to 20 inches deep are dug some time before planting and the young plants placed with the collar several inches below the top of the hole. Water and soil then slowly accumulate in the hole. Some problems arising out of the system are discussed by the authors. (*Agri. Amer.*, **7** : 90-2, 95, 1947).

VIRUS DISEASES OF CACAO IN TRINIDAD—II

BY

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Introduction

Posnette (1944) described two diseases of cacao from Trinidad which he attributed to separate viruses or virus strains. Experiments involving the transmission of these by budding showed that although reactions varied on different types of cacao their symptoms remained distinguishable. More extensive experiments and field studies have for the most part substantiated Posnette's observations, but certain of his tentative conclusions require modification. Although undoubtedly distinct, the two strains, described by Posnette as "red-mottle" and "vein-clearing," are similar; they will be known in this paper as "strain A" and "strain B" respectively. The original terms are unsuitable, since on certain types of cacao the symptoms of the "vein-clearing" strain include red-mottling of the leaves, and on others the "red-mottle" strain produces only mosaic. The symptoms resemble those of certain strains of the West African swollen shoot disease complex which do not cause swellings; the latter are not associated with virus infection in Trinidad. Posnette was of the opinion that the affected trees often showed signs of dieback and poor health, but owing to the general bad condition of the cacao in areas where the disease occurs, definite proof could not be obtained. More recently, observations on a field of ten-year-old vegetatively propagated I.C.S. varieties, in which strain A is spreading, have indicated that it can cause dieback and probably a reduction in yield.

A field survey, carried out by the Trinidad Department of Agriculture, has shown that the disease is largely confined to the western end of Trinidad's Northern Range, and is commonest in the valleys of Diego Martin, Santa Cruz and Maracas, where large cacao estates are situated. Smaller affected areas occur on the northern side of the range near Maracas Bay. Attempts are being made to eradicate an outbreak near Sangre Grande, attributed to the use of infected bud-wood from Diego Martin, and a few trees, presumably infected in the same way, have been removed at four estates in north-east and central Trinidad, (Text-fig. 1). It is likely that the incidence of the virus is greatest in Santa Cruz valley, which lies between Diego Martin and Maracas, and both strains are found there. Strain A alone occurs in the Diego Martin area and strain B alone in the Maracas valley. Posnette and Palma (1944) failed to find the virus in eastern Venezuela, and no trace of it was found in Grenada, St. Vincent, St. Lucia or Dominica in 1944 and 1945. Grenada was surveyed again in 1947 by Leeds and Winter (unpublished report) with negative results, and so far there has been no report of the disease from Tobago. Parts of this article have already appeared in the Annals of Applied Biology (Baker and Dale, 1947).

Symptoms

Strain A

On many cacao varieties this strain, common in the Diego Martin and Santa Cruz valleys and designated by Posnette as " red-mottle ", causes a reddish feather-like banding of some or all main veins of the young leaf (Pl. a). As the leaves harden and turn green this reddish vein-banding fades and disappears. Young cacao leaves vary in colour, for different varieties, from pale green through pink to dark red, and this symptom is not visible on trees whose young leaves are dark red, but is clearly defined on those which "flush" green or pink. Some form of mosaic, which persists after the leaves have hardened, usually accompanies the reddish vein-banding, but is notably absent on I.C.S. 6, 53 and 60, so that unless young leaves are present the disease cannot be diagnosed on these clones. The mosaic takes the form of cleared areas, varying in size and shape, bordering the main veins of the leaf. There is no definite continuous "vein-clearing", although on some clones, such as I.C.S. 98, this condition is approached. Mosaic symptoms differ markedly from tree to tree in seedling plantations and from clone to clone in plantings of vegetatively propagated trees. Thus, the clones I.C.S. 3 and 7 show a very well-marked mosaic (Pl.b) while that produced on I.C.S. 1 is very slight and often difficult to recognise. Mosaic is usually associated with red-mottling on young leaves, but the latter is not found on certain varieties.

Cacao trees in Trinidad put out new leaves four or five times a year in definite "flushes" of growth. By no means all the leaves of any one flush on an infected tree will show the effects described above, and it is not unusual for symptoms to be restricted to a few veins of one or two leaves, or even to be entirely absent for a time. It has been observed that certain trees which have been diseased for several years and have ceased to grow vigorously may seldom, if ever, show leaf symptoms, and a budding experiment has demonstrated that such trees still contain the virus in an active condition. The lowest or first produced leaf of the new growth on a shoot is not only the likeliest to show symptoms, but will do so more markedly than subsequently expanding leaves, which are often symptomless. Strain A also causes red blotches on the young pods of certain yellow-podded cacao varieties, like I.C.S. 6 and 8. Recent observations indicate that this strain can cause dieback and probably a reduction in yield in comparatively young trees. There is at present no evidence that relatively mild leaf symptoms are any indication of tolerance to the disease in cacao varieties; even at their greatest development the leaf patterns are not striking by comparison with those of most other plant virus diseases. According to Posnette, crinkling of the leaf and

necrosis of the leaf-tip may be associated with both this strain and strain B, but we do not consider these symptoms to be due to virus infection.

Strain B

This strain, described by Posnette as "vein-clearing", occurs in the Maracas valley and parts of the Santa Cruz valley. Although it is similar to strain A, bud transmission experiments have shown that slight though constant differences exist. The chief of these is that on most kinds of cacao a continuous vein-clearing, often extending to the fine veins of the leaf, is produced; this persists after the leaves have hardened (Pl. d, e, f). An evanescent reddish vein-banding occurs on the young leaves of a few varieties. The clone I.C.S. 6, when infected with strain A, develops red vein-banding only; but this is accompanied by mosaic when infection is by strain B (Pl. c), giving symptoms similar to those of strain A on certain other clones. I.C.S. 6 can therefore be used as a differential host for identifying the two strains. The leaf symptoms of strain B, although slightly more striking than those of strain A, behave in a similarly erratic manner, often being restricted to a few leaves on a tree at any time. The effect of this strain on the condition and yield of cacao has not been assessed, due to the general bad condition of almost all trees, infected or otherwise, in the areas where it occurs.

Field Observations

Experiments were started early in 1944 to determine the rate of spread of strain A under plantation conditions. For this purpose a field of ten-year-old I.C.S. cacao, planted at River Estate in the Diego Martin valley, was available (Text-fig. 2), and its study has proved of the greatest value and interest. The first survey of the disease in this field was made in April 1944, since when it has been under continuous observation. Six clones are present, I.C.S. 1, 3, 4, 5, 6, and 8, the lay-out being a randomised block, replicated six times, with sixteen trees per plot. There are therefore 96 trees of each clone and a total of 576 trees in the field; but of the original 576, 22 have died and been comparatively recently replaced (Text-fig. 2, R), leaving 554 trees on which our observations are based. Most of the replacements occur in plots of I.C.S. 5, which is particularly susceptible to cacao beetle attack. Individual tree yield records are kept by the Botany Department of the Imperial College of Tropical Agriculture, the pods being harvested at approximately monthly intervals. The number of pods yielded by the trees of each variety in 1944, 1945, 1946 and 1947 is shown in Table I. Diseased pods, mainly due to witches' broom disease, which attain full size are included.

1945 was a good year for cacao at River Estate but 1946 and 1947 were bad ones, the total yield falling off considerably. Two of the clones (I.C.S. 3 and 5) have yielded outstandingly badly in this field, but the drop in yield in 1946 was largely due to I.C.S. 1, 3 and 8, which showed a serious falling off, while I.C.S. 4, 5 and 6 maintained their yields.

TABLE I

Total yield, in pods, of I.C.S. cacao varieties

I.C.S.	1944	1945	1946	1947
1	1984	2506	1278	664
3	489	842	399	56
4	774	1006	1015	308
5	237	653	509	240
6	1506	1720	1547	575
8	2136	3021	1682	632
Total	7096	9748	6428	2475

In 1947 there was a considerable further drop in yield for all the clones, due presumably in part to the severe drought experienced during the first part of the year.

In April 1944 there were 45 virus-infected trees, diagnosed on the basis of leaf symptoms; three years later there were 242, representing 43.7% of the trees in the field (Table II).

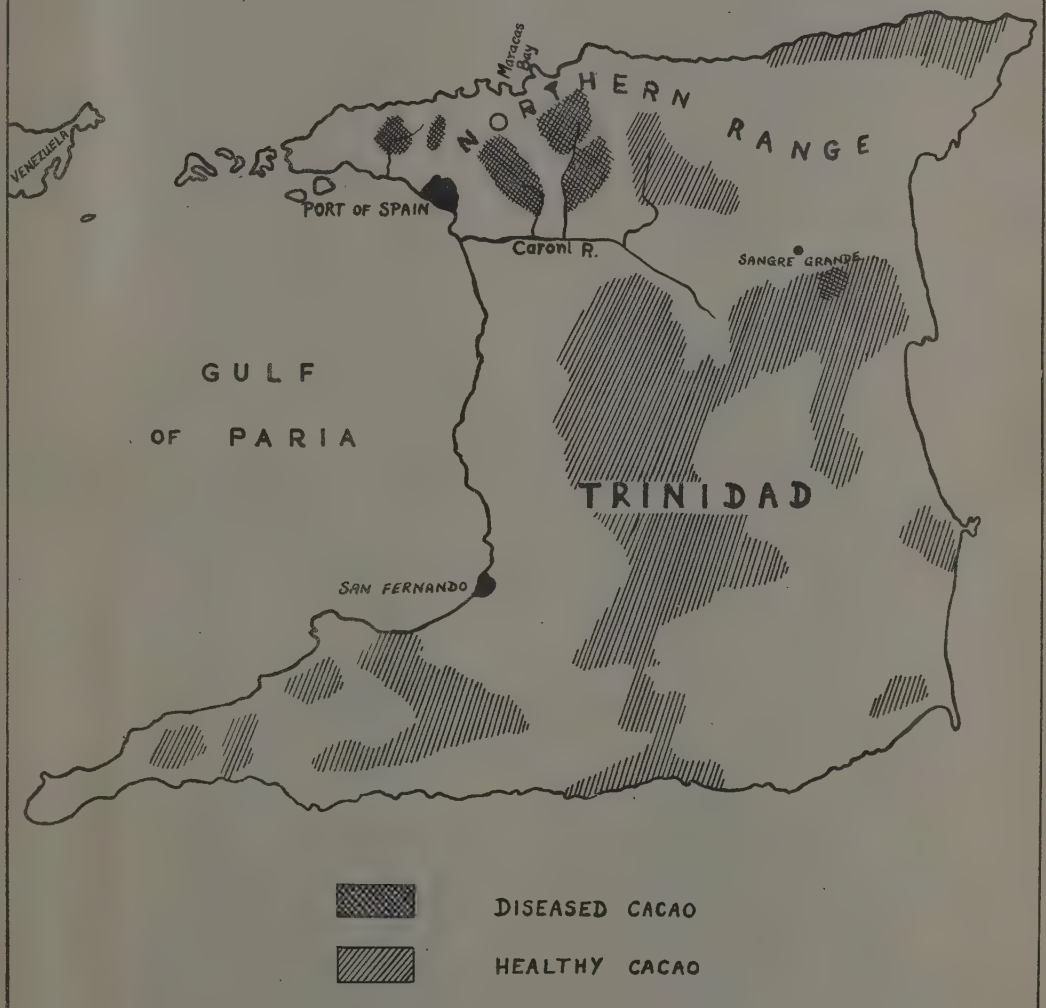
TABLE II

Numbers of diseased trees for each clone

I.C.S.	11.4.44	1.2.45	4.3.46	11.3.47
1	6	11	19	30
3	6	13	22	36
4	7	14	21	37
5	5	12	19	37
6	17	32	47	69
8	4	9	13	33
Total	45	91	141	242

As would be expected, the rate of spread has tended to increase as the number of diseased trees has increased. Table II shows the number of infected trees for each clone at approximately annual intervals. The number of diseased trees of I.C.S. 1, 3, 4, 5 and 8 is similar, but I.C.S. 6 has about twice as many as any other clone. At present we would hesitate to suggest that I.C.S. 6 may be more susceptible to infection by the virus than other clones. The mode of spread of the disease over short distances is well illustrated by Text-fig. 2, which is a map of the distribution of infected trees, diagnosed in seven successive surveys. Each small square represents a plot of sixteen cacao trees and the numbers indicate the survey in which infection of any particular tree was first observed.

TEXT-FIGURE 1



It has become increasingly obvious that certain trees in this field are unhealthy (Text-fig. 2, O). Their appearance is attributable to various features, alone or in combination, including small size, cessation of growth, dieback, "stag-headedness", the development of small leaves and out of season flushing. When several of these trees occur together, as they often do, the canopy is noticeably poor and light. Since the distribution of the virus-infected trees is not a random one, no straightforward statistical treatment to investigate the possibility of a correlation between virus infection and unhealthy appearance is available; but an analysis of the field into "good" and "bad" and virus-free and virus-infected trees, made in March 1947, is given in Table III.

Of the 312 virus-free trees only 6% were in bad condition, while of the 242 virus-infected trees 40% showed symptoms of ill-health.

TABLE III

Condition of trees and virus infection

I.C.S. clone	Virus-free* Good	Bad	Virus-infected* Good	Bad	Total
1	61	5	20	10	96
3	57	3	21	15	96
4	58	1	26	11	96
5	33	6	28	9	76
6	22	3	28	41	94
8	62	1	22	11	96
Total	293	19	145	97	554

* On the basis of presence or absence of visible leaf symptoms.

TABLE IV

Condition of trees and period of virus infection

Period infected (to March 1947)	Over 3 years	2–3 years	1–2 years	Up to 1 year	Not attacked
Total trees	45	46	50	101	312
Bad trees	25	27	19	26	19
Percentage bad trees	56	59	38	26	6

Table IV indicates that the groups infected longest (two years and over) had a higher percentage of unhealthy-looking trees than the groups attacked more recently. Of the nineteen virus-free bad trees, three have since been shown by a budding experiment to be infected but without leaf symptoms; four are on the northern boundary of the field and exposed to the prevailing wind; others may have been damaged by cacao beetles or by falling banana plants and immortelles. Nine of them occur in a group towards the western end of the field and their poor condition may be due to a patch of poor soil or gravel as the immortelle shade in the vicinity is also poor. In spite of the absence of a statistical analysis, the conclusion that the virus disease is doing serious damage to the trees seems to be unavoidable.

The effect of the virus on yield has been examined by a study of the subsequent production of the 45 "originally diseased" trees found in April, 1944. The mean yields for each clone over the last 4 years, in pods per tree, are compared in Table V with the corresponding figures for trees still uninfected in March, 1947.

In 1944 the diseased trees yielded consistently better than the healthy ones; in 1945 they yielded slightly worse; in 1946 the average yield from diseased trees for some clones was a little less, although I.C.S. 1

TABLE V

Yields of infected and virus-free trees (pods per tree)

	1944		1945		1946		1947	
I.C.S.	*Infected*	*Virus-free*	*Infected*	*Virus-free*	*Infected*	*Virus-free*	*Infected*	*Virus-free*
1	19.0	18.5	17.8*	25.3	16.3	11.4	4.8*	6.8
3	5.7	4.0	9.0	7.6	2.8*	3.8	0.2*	0.6
4	10.1	7.4	7.9*	10.0	7.3*	10.4	1.0*	3.1
5	3.2	3.0	9.2	6.2	5.8*	6.6	1.2*	3.2
6	23.4	12.8	16.3	15.3	18.6	17.9	3.8*	7.6
8	24.0	19.5	23.7*	29.9	6.7*	15.9	1.3*	7.4

* Below the comparable yield for healthy trees.

was a notable exception. The average yield from diseased trees of all the clones was lower in 1947 than that of uninfected ones. The figures suggest the possibility that the infection of a tree by strain A may stimulate it at first to produce more cacao, but result after a few years in a decreasing yield. The former could be the result of interference by the virus with the translocation of food materials in the tree, producing an effect similar to that caused by ring-barking on many fruit trees. An eventual reduction in yield is to be expected from our observations on the appearance of the diseased trees. On the basis of figures at present available these apparent effects of virus infection should not be stressed too strongly, but the indications are that an adverse effect on the yield of these ten-year-old trees is developing, which may well become more obvious in later years.

Transmission

Posnette readily transmitted both strains by budding. With strain A the interval between budding and the appearance of symptoms varied from 94 to 119 days, while with strain B two of his plants developed symptoms in 45 and 60 days, respectively, suggesting a shorter incubation period for this strain. Our results indicate that this difference was due to chance, and that the strains cannot be differentiated in this way. The maximum and minimum incubation periods found in our series of experiments were, respectively, 125 and 34 days for strain A and 136 and 61 days for strain B. No symptoms of either strain can be observed until the plants flush, and if this occurs shortly after budding and the next flush is long delayed, a very long incubation period inevitably results. The period will also vary with the suitability of the conditions for the growth of cacao, so that the mean of 90 days obtained in our experiments can only be regarded as a general indication. The long incubation period and the erratic production of leaf symptoms suggest that the virus does not spread rapidly through the host tissues. This is supported by the observation that the first produced leaf of the new growth on a shoot almost invariably shows the most marked symptoms, whereas those expanding later may be quite symptomless. The development of a flushing cacao shoot is very rapid, and the virus may be incapable of increasing in amount sufficiently rapidly to have much effect on the younger leaves.

Preliminary trials with insects have shown that strain A can be transmitted by more than one species of mealy bug, the incubation periods so far recorded ranging from 20 to 117 days. These insect vector investigations are continuing. It is of interest to note that mealy bugs have been proved to be vectors of strains of the West African swollen shoot virus disease complex.

Attempts to transmit the Trinidad strains by mechanical inoculation have failed and there is no evidence of seed transmission.

Summary

The results of further experiments and observations on the virus disease of cacao, first reported from Trinidad by Posnette (1944), are presented. The virus, of which there are two very similar but distinct strains, still appears to be largely confined to the western end of Trinidad's Northern Range. The two strains described by Posnette as "red-mottle" and "vein-clearing", are re-named strains A and B, respectively, and their symptoms are described. For both strains the appearance of leaf symptoms is rather erratic, often being restricted to a few shoots or even a few leaves on a tree at any time.

The manner and rate of spread of strain A in a field of ten-year-old clonal cacao was studied over a three-year period, during which time the number of diseased trees out of a total of 554 increased from 45 to 242. From a study of the condition of virus-free trees and those infected for varying periods, in the same field of clonal cacao, it is clear that the disease is producing dieback; of the 242 infected trees 40% showed symptoms of ill-health, while only 6% of the 312 virus-free trees were in bad condition. There are also indications that an adverse effect on yield is developing as a result of infection.

Both strains were readily transmitted by budding, their incubation periods, which were comparable, ranging from 34 to 125 days for strain A and 45 to 136 days for strain B. These vary with the growth conditions and the time elapsing between budding and the following flush. Preliminary trials have shown that more than one species of mealy bug can transmit strain A. Neither strain has been transmitted mechanically and there is no evidence of seed transmission.

References

Baker, R. E. D. & Dale, W. T. (1947) Notes on a Virus Disease of Cacao. *Ann. App. Biol.* XXXIV, pp. 60-65.

Posnette, A. F. (1944) Virus Diseases of Cacao in Trinidad. *Trop. Agriculture, Trin.* XXI, pp. 105-106.

Posnette, A. F. (1944) & Palma, M. Observations on cacao on the Paria Peninsula, Venezuela *Trop. Agriculture, Trin.* XXI, pp. 130-132.

ERRATA

FERTILIZER FIELD EXPERIMENTS WITH SUGAR-CANE ON PHOSPHATE-DEFICIENT SOILS IN SOUTH TRINIDAD VOL. 24 (NOS. 5-7), 1947

Page 94, column 2, paragraph (*b*), line 4: For "2 cwt. per acre" read "*3 cwt. per acre*".

Page 105, column 1, line 2: For "the two largest values" read "*the two lowest values*".

Page 106, column 2, last line but 3: For "10 per cent." read "*70 per cent.*".

Page 104, Table IV—H.54: The correct fertilizer treatments appear in the first column of the table for Plant Canes and last column for First Ratoons.

THE EFFECTS OF MULCHING DERRIS ELLIPTICA

BY

DAVID G. WHITE, CALEB PAGAN* AND JOSE C. MANGUAL†

Introduction

Derris elliptica (Wall.) Benth. is a tropical leguminous plant grown for the insecticide rotenone which is found in the roots. *Derris* is usually propagated from stem cuttings and field plantings are cultivated by hand (2, 3). To our knowledge, the effects of mulching *Derris* with leaves of other material has not been reported previously. In this article no attempt will be made to refer to the large amount of literature available on the advantages and disadvantages of mulching plants in a temperate climate since relatively few experiments have been reported on the effects of mulching tropical plants (4).

Experiment I

A level field of Toa clay loam 50 to 60 feet above sea level was chosen for all experiments. This soil has been in cultivation for many years and is of low fertility and in relatively poor tilth. In the first experiment 588 rooted cuttings of the MG-1 clone of Changi III (5) were planted 2 feet apart in rows spaced a distance of 3 feet and ridged 8 inches high. The planting was made between October 11 and 13, 1944. On November 15 the field was marked into 12 plots, 7 plants long and 7 plants wide; mulches of sugar cane leaves were applied on 8 plots so that similar treatments were not adjacent. Two levels of mulch were employed : 4 plots with 12 inches and 4 plots with 6 inches. The 4 additional plots were maintained as checks not mulched (Fig. 1). A second application of mulch to maintain the original depths was made between August 1 and 3, 1945; a third application was made on February 17, 1946. Periodic measurements of soil moisture were made by sampling at a depth of 6 inches in 2 places within each plot. Duplicate aliquots of the composited samples for each treatment were then dried in an oven at 110° C. for 24 hours and the percentage moisture was expressed on an oven-dry basis.

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TABLE 1—SOIL MOISTURE BENEATH *Derris* MULCHED WITH DIFFERENT AMOUNTS OF SUGARCANE LEAVES.

Date Sampled	Rainfall previous week	Soil Moisture Content		
		Check no mulch	6 inches of sugarcane leaves*	12 inches of sugarcane leaves*
1945-46	*inches*	*percent*	*percent*	*percent*
February 6	0.03	20.8	24.8	29.2
March 13	0.00	15.2	20.9	26.1
April 24	0.39	21.7	28.7	32.1
May 15	0.44	23.6	30.6	33.5
June 19	6.41	28.4	35.2	34.4
July 16	3.13	26.8	37.3	44.2
August 1	4.17	24.9	31.4	31.3
September 4	2.48	28.9	34.3	33.4
November 28	0.21	20.7	21.4	31.6
December 28	2.20	24.7	23.3	27.0
January 28	0.72	26.4	28.4	26.5
February 18	0.43	17.9	19.6	26.7
April 30	1.98	19.7	21.6	29.1
June 26	0.19	17.6	19.7	26.8
Average	—	22.7	26.9	30.9

* Mulch applied November 15, 1944, August 1, 1945, and February 17, 1946.

TABLE 2—YIELD OF *Derris* ROOTS PRODUCED UNDER TWO DEPTHS OF MULCH AND HARVESTED AT DIFFERENT AGES.

Treatment *	Diameter of roots	Dry weight of roots harvested at		Average total dry weight
		24 months	26 months	
	millimeters	*grams*	*grams*	*grams*
Check, no mulch	0—4	180	255	
	4—8	333	578	
	8+	481	528	
	(Total)	(994)	(1361)	1178
6 inches of sugarcane leaves	0—4	216	327	
	4—8	468	713	
	8+	599	781	
	(Total)	(1283)	(1821)	1552
12 inches of sugarcane leaves	0—4	320	319	
	4—8	535	683	
	8+	841	566	
	(Total)	(1696)	(1568)	1632

* Mulched 1, 9, and 15 months after planting.

TABLE 3—ROTENONE CONTENT OF *Derris* ROOTS HARVESTED AT DIFFERENT AGES AND PRODUCED UNDER TWO DEPTHS OF SUGARCANE MULCH.

Treatment	In roots harvested at :		Average
	24 months	26 months	
	percent	*percent*	*percent*
Check, no mulch	8.5	7.7	8.1
6 inches of sugarcane leaves ...	8.8	8.0	8.4
12 inches of sugarcane leaves ...	7.9	8.1	8.0

On October 11, 1946, 2 years after planting, the roots of the 25 centre plants in 2 plots of each treatment were harvested by spade to a depth of 16 inches. The roots were then washed, separated into diameter groups of 0—4, 4—8, and larger than 8 mm., air-dried, and weighed. Two months later the remaining 2 plots of each treatment were similarly harvested and the content of rotenone in the roots of each plot was determined gravimetrically (1). Statistical analyses were not performed on these data because of insufficient replicates.

The percentages of soil moisture beneath the different mulches and in the check plots are given in Table 1. Soil moisture was correlated to some extent with the rainfall of the previous week, also presented in Table 1. In all but one instance the soil moisture of the mulched plots was higher than that of the check plots. With 4 exceptions, the soil moisture was higher in the plots mulched with 12 inches of sugarcane leaves than in plots mulched with 6 inches.

The average dry weights of the roots from each treatment, harvested 24 and 26 months after planting, are presented in Table 2. In all cases the smallest quantities of roots were obtained in the 0 to 4 mm. diameter class. With the exception of two instances the largest quantity of roots was more than 8 mm. in diameter. The weight of roots in each diameter class was larger for those harvested at 26 months than at 24, except roots 0 to 4 mm. and more than 8 mm. in diameter produced under 12 inches of sugarcane leaves. On the basis of the total dry weight, *Derris* mulched with 6 inches of sugarcane leaves produced 31.7 per cent. more roots than the check plants and those mulched with 12 inches of leaves produced 38.5 per cent. more roots.

The roots of each diameter class within each treatment were composited for chemical analyses of rotenone. These data are presented in Table 3 as per cent. rotenone on an oven-dry basis. There did not seem to be any consistent difference in rotenone content associated with mulching or the age at harvest.

THE EFFECT OF MULCHING DERRIS ELLIPTICA

FIGURE 1.—*Derris elliptica* 3 months after mulching with sugar-cane leaves. Experiment 1.

THE EFFECT OF MULCHING DERRIS ELLIPTICA

FIGURE 2.—Plants of Sarawak Creeping *Derris* grown from cuttings which had not been rooted planted under: Left to right, Manila hemp leaves, white roofing paper, lemon grass leaves, and black roofing paper (Experiment III). Photograph was taken July 18, 1946, about 8 months after planting.

Experiment II

In the second experiment 1,568 rooted cuttings of the same clone were planted in a similar manner to the first experiment except 4 of the 8 check plots were level and not ridged. Planting was done between January 25 and 29, 1945. Each plot was 7 plants long and 7 plants wide. Between March 1 and 7, 1946 three different types of mulches were applied at different depths on 4 replicate plots in a randomized block design as follows: (1) Sugarcane leaves, 6 inches deep; (2) sugarcane leaves, 12 inches deep; (3) lemon grass leaves, 6 inches deep; (4) lemon grass leaves, 12 inches deep; (5) derris debris of partially decomposed leaves and stems of previous harvests, 3 inches deep; and (6) derris debris, 6 inches deep. Second applications of the sugarcane and lemon grass leaves were made at the specified depths between August 1 and 3; third applications were made on February 18 and 19, 1946. No additional derris debris was added because it did not decompose as rapidly as the other mulches. Soil temperatures at a depth of 3 inches in a plot mulched with 12 inches of lemon grass leaves were measured simultaneously with temperatures in an adjacent check plot, using a Foxboro Soil Thermograph equipped with two sensitive units. Similarly soil temperatures were measured at a depth of 5 inches beneath 12 inches of lemon grass leaves and also at depths of 6 inches beneath 12 inches of sugarcane leaves. Records were also maintained of the man-hours required for weeding each plot. Between January 8 and 15, 1947, 2 years after planting, the roots of the 25 center plants in each plot were harvested, weighed, and analyzed as in the first experiment. An analysis of variance was performed on these yield data.

Data illustrating the differences in soil temperatures are summarized in Table 4. Air temperatures were often 7 to 10 degrees lower than the lowest soil temperatures recorded. The highest soil temperatures beneath the mulches were always lower than the highest air temperatures. The soil temperature beneath the mulched plots was sometimes 16 degrees lower than that of the check plots at the same hour. Soil temperatures at a depth of 3 inches were in general a few degrees higher than at 6 inches. However, this difference may have been caused to some extent by corresponding higher air temperatures at the time soil temperatures were measured at a depth of 3 inches. Soil temperatures under sugarcane leaves never became as high as in earlier measurements under lemon grass, although air temperatures were in a comparable range. The second application of mulch made in early August no doubt helped maintain lower temperatures within these plots. Also, a more even distribution of rainfall during this period was probably a contributing factor. In all cases both types of mulch resulted in a narrower range of soil temperatures which never became as high as temperatures of the check plots. Soil temperatures of plots subject to other types of mulch were not measured.

Most of the weeding was necessarily done by hand to suppress nutgrass, *Cyperus rotundus* L. These data are summarised in Table 5, where it will be noted that mulching with sugar-cane leaves required the least amount of labour for weeding. Less than half the man-hours necessary to weed the check plots were required to weed plots mulched with sugar-cane leaves. Apparently 6 inches of sugar-cane leaves was about as efficient in suppressing weed growth as 12 inches. Sometimes sugar-cane sprouts arose but these were easily pulled at an early stage. Although lemon grass mulch did not suppress weeds as well as sugar-cane leaves, these plots required considerably less weeding than check plots. Lemon grass leaves applied 12 inches deep suppressed weeds better than when applied 6 inches deep. Derris debris 3 inches deep did not control weeds but, on the contrary, contained numerous weed seeds which were a source of additional infestation. However, 6 inches of derris debris apparently smothered growth from weed seeds which germinated at lower depths and thereby required less labour than for weeding plots mulched with 3 inches. In either case derris debris cannot be considered a satisfactory mulch from the standpoint of weed control.

TABLE 4—Soil Temperatures in Plots of *Derris* Mulched and Not Mulched.

Treatment*	Depth measured	Range in soil temperatures	Range in air temperatures
1945	*inches*	°F	°F
May 17 to June 12 :			
12 inches lemon grass leaves ...	6	73—82	66—94
Check, no mulch	6	73—97	66—94
June 28 to August 20 :			
12 inches lemon grass leaves ...	3	74—87	67—97
Check, no mulch	3	74—100	67—97
August 20 to November 13 :			
12 inches sugarcane leaves ...	6	74—80	64—95
Check, no mulch	6	74—90	64—95

* Mulched between March 1 to 7 and August 1 to 3.

TABLE 5—Labour Required During 1945 for Weeding Plots of *Derris* Mulched and not Mulched.

Treatment*	Man-hours†	Percent of total
	hours	*percent*
Check, no mulch, level	37.15	14.0
Check, no mulch, ridged	43.32	16.4
6 inches sugarcane leaves	18.11	6.8
12 inches sugarcane leaves	17.24	6.6
6 inches lemon grass leaves	31.10	11.7
12 inches lemon grass leaves	26.23	9.9
3 inches derris debris	51.09	19.3
6 inches derris debris	40.42	15.3

*Mulched between March 1 to 7 and August 1 to 3.
†196 plants in each treatment.

TABLE 6—The Yield of Air-Dry Roots of *Derris* Produced Under Different Types of Mulch.

(Average of 25 plants per plot)

Treatment*	Dry weights according to diameter of			Average total dry weight‡
	0-4 mm.	4-8 mm.	8 mm.	
	grams	*grams*	*grams*	*grams*
Check, level	93	284	214	591
Check, ridged	88	264	285	637
6 inches of sugarcane leaves	145	491	434	1070
12 inches of sugarcane leaves	168	581	442	1191
6 inches of lemon grass leaves	147	469	551	1167
12 inches of lemon grass leaves	139	356	310	805
3 inches of *Derris* debris †	131	458	378	967
6 inches of *Derris* debris †	142	653	496	1291

*Mulched 1, 6, and 11 ½ months after planting.
†Mulched only once 1 month after planting.
‡12 inches of sugarcane leaves and 6 inches of derris debris were significantly greater (odds 19:1) than the two check treatments ; 6 inches of lemon grass leaves was significantly greater (odds 19:1) than the check level.

The yield of roots from each treatment harvested 24 months after planting are presented in Table 6. Yields in this experiment were lower in general than those in the first experiment. In all cases the smallest quantity of roots were in the 0– to 4–millimeter diameter class. With the exception of two instances the largest quantity of roots were in the 4– to 8–millimeter diameter class. There was little difference in the quantity of roots produced in the level and ridged check plots. Significantly more roots were produced in the plots mulched with 12 inches of sugar-cane leaves and plots mulched with 6 inches of derris debris than in the check plots. Plants mulched with 6 inches of lemon grass produced significantly more roots than the level check plots. No other significant differences in yields were found probably because of the large variation among yields from plots of the same treatment.

The distribution of roots beneath mulched and check plots appeared to be similar. Practically all of the mulches in this and the first experiment were decomposed by the time of harvest. No difference in the amount of labour required for harvesting the various plots was noted. Apparently mulching did not induce roots to congregate nearer the soil surface and thereby facilitate harvesting.

TABLE 7—THE AVERAGE ROTENONE CONTENT AND YIELD OF ROTENONE IN ROOTS OF *Derris* PRODUCED UNDER DIFFERENT TYPES OF MULCH.

Treatment*	Rotenone content	Yield of rotenone per 25 plants‡
	percent	*grams*
Check, level	7.3	42.8
Check, ridged	7.2	46.7
6 inches of sugarcane leaves	7.4	78.6
12 inches of sugarcane leaves	7.2	88.6
6 inches of lemon grass leaves	7.9	90.7
12 inches of lemon grass leaves	7.6	60.7
3 inches of derris debris †	6.3	69.8
6 inches of derris debris †	7.4	81.5

* Mulched 1, 6, and 11 ½ months after planting.

† Mulched only once 1 month after planting.

‡ 12 inches of sugarcane leaves and 6 inches of lemon grass leaves were significantly greater (odds 19:1) than the two check treatments ; 6 inches of derris debris was significantly greater (odds 19:1) than the check level

TABLE 8—AVERAGE SURVIVAL OF *Derris* PLANTS ONE YEAR AFTER PLACING CUTTINGS WHICH WERE NOT ROOTED IN THE FIELD UNDER DIFFERENT MULCHES.

(24 cuttings planted per plot)

Treatment	PLANTS ALIVE	
	Number	Percent
6 inches of lemon grass leaves	20.8	86.7
3 inches of Manila hemp leaves	17.8	74.2
Black roofing paper	11.1	46.3
White roofing paper	15.5	64.6

The roots of each plot were composited for chemical analyses of rotenone and these results are presented in Table 7, together with the average yield of rotenone produced with each treatment.

The actual yield of rotenone per unit number of plants is of most importance because it represents the evaluation of the crop. In this experiment the yield of rotenone from *Derris* mulched with 12 inches of sugar-cane leaves and mulched with 6 inches of lemon grass were significantly greater than yields from the check plots. Mulching with 6 inches of derris debris resulted in a significantly greater production of rotenone than from check plants grown on level soil.

Experiment III

The third experiment was designed to study the possibility of establishing cuttings which had not been rooted in the field under mulch, thus by-passing the standard method of rooting the cuttings in a nursery for one year before setting to the field. For this purpose 672 10-inch cuttings of the Sarawak Creeping variety were planted on November 23, 1945, in 32 rows ridged 8 inches high with 3 feet between rows. Cuttings were inserted 1 foot apart at a 45° angle with the distal bud exposed and facing up. On the same day the following mulches were applied on separate rows replicated 8 times : (1) Lemon grass leaves, 6 inches deep ; (2) Manila hemp leaves (*Musa textilis* Nee), 3 inches deep ; (3) black asphalt roofing paper ; and (4) black asphalt roofing paper painted white on the exposed surface. One year later the number of living plants established in each plot was recorded. At this time only vigorous plants remained, figure 2.

The results are presented in Table 8 where it will be noted that 86.7 per cent. of the cuttings planted under 6 inches of lemon grass developed into vigorous plants. Fewer cuttings developed into plants under the other mulches. In this experiment a soil thermograph was employed to measure temperatures 3 inches deep beneath the black and the white

roofing paper mulches. Usually the soil temperature beneath the black paper was 8 to 10° F. higher than that beneath white paper each day. The higher temperature under the black paper may have been the cause for fewer cuttings rooting than under white paper. In both paper mulches the distal buds were exposed to the sun which caused the death of many young stem tips. With the leafy mulches the distal buds were somewhat protected by the mulch which was placed around but not on top of the buds. The Manila hemp leaves, which shrivelled badly, required two replacements and did not constitute a good mulch. Very little weeding was required throughout the year in comparison with the large amount of work necessary to maintain nursery plantings.

Summary and Conclusions

1. Experiments were conducted to determine the effects of various mulches on the maintenance and yield of *Derris elliptica*. Mulching was found to be associated with higher soil moisture contents and lower soil temperatures than in check plots during dry weather and the hot period of each day respectively.

2. Considerably less labour was required to weed *Derris* mulched with grass leaves than plants mulched with *Derris debris* or not mulched at all. Mulching did not seem to influence the amount of labour involved in harvesting the roots at the end of the experiment.

3. The yield of roots from *Derris* mulched with sugar-cane or lemon grass leaves was usually significantly higher than from check plots not mulched.

4. The rotenone content of *Derris* roots was not adversely affected by mulching and in some instances was higher than in roots from check plots. The actual yield of rotenone per unit number of mulched plants was generally higher, and in some instances significantly higher than from check plants.

5. Unrooted cuttings of *Derris* were placed directly in the field under mulch and one year later more than 86 per cent. of those mulched with 6 inches of lemon grass leaves had developed into vigorous plants.

6. The practical value of mulching *Derris* plantings is demonstrated, its application being dependent upon the availability of satisfactory mulching material.

References

1 Association of Official Agricultural Chemists (1940). Official and Tentative Methods of Analysis 5th Edit., Washington, D.C. 757 pp. (See pp. 64-65).

2. Moore, Rufus H. (1943). Derris culture in Puerto Rico. *Puerto Rico (Mayaguez) Fed. Expt. Sta. Circ.* 24, 1-17.

3. White, David G. (1945). Propagating *Derris* by cuttings. *Agr. in the Americas* 5 : 154-156.

4 ——— (1947). Mulching tropical plants. *Agr in the Americas* (in the press).

5 ——— and Villafane, Aida G. (1946). Insecticidal crop investigations. *Derris* cutting experiments. *Puerto Rico (Mayaguez) Fed. Expt. Sta. Rpt.* 1945 : 6-9.

CINCHONA IN UGANDA *

In an article published in the *Emp. J. exp. Agri.*, 14 ; 75-84, the author describes the cultivation of cinchona in Uganda under the following headings ; (1) historical, (2) selection, (3) climatic and soil requirements, (4) cultivation, (5) pests and diseases, (6) costs, yields and returns. The production of quinine by a cinchona tree depends not only on the richness of the bark but also on the thickness of the bark and the growth of the tree. To estimate the relative value of trees the figure used has been the product-percentage of quinine sulphate × girth of tree × weight of sample. Most of the trees sampled were vigorous ; many had more than one stem ; of those which had a single stem few had a girth of less than 50 cm. at a height of 1 metre above ground-level ; the largest tree with a single stem had a girth of 76 cm. As seedlings of *Cinchona josephiana* grow so well in Uganda there is no question of using the more expensive grafted plants for commercial quinine production. Seed has been collected from many of the best trees and their progenies are being planted out for observation. Preliminary trials of side-grafting indicate that the clones differ greatly in the ease with which they may be propagated in this way. Cinchona has been found to grow well on the heavy red earths so common in Uganda ; if these red earths are too much cultivated when wet their physical condition is bad, but if cinchona is planted on them soon after the land has been cleared from elephant grass and the structure is good the crop grows well. It is essential that nursery beds should be arranged so that seeds are exposed to light but are protected from rain ; if the soil is too wet, the seedlings will become attacked by Rhizoctonia and will die off. Crickets are a nuisance in nursery beds. The mosquito bug, Helopeltis (orophila), attacks seedlings during dry spells, but it can be controlled by dusting with pyrethrum powder. Large grasshoppers sometimes do much damage. Cinchona is very liable to death from root rot caused by Armillaria mellea ; land under elephant grass, where the fungus is rare, is recommended for cinchona in preference to forest soils where the fungus is often abundant.

* (*Horticultural Abstracts*, 17, 212, 1947).

LUCKY HILL COMMUNITY PROJECT

BY

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In his 1940-42 report on Development and Welfare in the West Indies, Sir Frank Stockdale states that land settlements have been established throughout the West Indies as a palliative to agrarian discontent. The creation of small holdings on an unrestricted freehold basis has ever proved a costly undertaking and, as a rule, has been disappointing to the settlers. Despite all the weight of evidence against this system of land settlement, it remains the popular choice of Jamaica. Literally no caution is employed in approach to land settlement in this popular and accepted form, yet the need for extreme caution is preached when any alternative method of settlement is mentioned.

Lucky Hill Community Project is unique. It is the one and only experiment of its kind in land settlement, not only in Jamaica but in the whole of the British West Indies. Even so the scheme has not been given the attention which it deserves. Wrong conceptions at the start, inattention because of inadequate trained assistance, lack of faith, and perhaps, the practice of extreme caution in approach to the financial aspects of the problem well nigh wrecked the scheme. It says much for the soundness of the scheme that after all the vicissitudes of the early years, some degree of success is now being achieved. It is the desire of the settlers that the scheme should be publicised in the hope that similar projects will be developed elsewhere in Jamaica. Further requests for publicity have come from the Peasant Investigation Committee in Trinidad and also from many interested persons who have recently visited Lucky Hill.

Objects of the Scheme

In its broad concept, the Lucky Hill scheme was to test out a method of introducing the agricultural worker to estate-scale agriculture. The standards of living in Jamaica are dependent upon the intensive use of land. The advantages of large scale enterprise are obvious. A measure of small holdings will always be necessary, but the number should be kept to the minimum requirements of a balanced policy of agricultural development. The Jamaican, possibly through lack of understanding and knowledge, has an innate desire to own land, to be his own master rather than serve an employer. The Lucky Hill Project is an attempt to meet both aspects of the situation. Lucky Hill property is worked as one large concern, but all persons working on the project have a say in its management and a financial interest in its operation. Other factors which are provided for as integral parts of the scheme are:—

(a) The establishment of the happy family unit as the basis of society.

(b) The education and training of the persons participating in the scheme to develop initiative and self-help.

(c) The development of the co-operative spirit in all its aspects.

(d) Efficiency in land utilisation.

(e) The testing of leasehold land tenure.

Inception of the Scheme

The project may be said to have had its origin in 1940. In that year the Government Food Production Board, with the object of furthering the Food Production Campaign and at the same time providing relief for unemployed agricultural workers, leased, with the option to purchase, Lucky Hill Pen, a Red Poll cattle property or estate of some 873 acres in the Parish of St. Mary. Funds for operating the scheme were provided by Government. In the vicinity of Lucky Hill Pen is Walkerswood district, where a Pioneer Club, sponsored by Jamaica Welfare Ltd. was in operation. On the invitation of Government, the Pioneer Club agreed to operate 100 acres of the project on a communal basis. The operation of the project was placed in the hands of a committee of interested persons and representatives of the workers under the chairmanship of an officer of Jamaica Welfare Ltd. It was felt that by this arrangement, social welfare activities among the workers would receive attention. Subsequently, four more pioneer clubs were formed in the vicinity of Lucky Hill and eventually all operations on the Lucky Hill property were conducted by these clubs.

After operating on this basis for some time it was found necessary to transfer the supervision of the scheme from the Government Food Production Board to the Department of Agriculture. This transfer was effected in 1942 by which time Government had sustained very considerable financial losses. The scheme was now completely revised in accordance with the recommendations of Mr. A. J. Wakefield, then Agricultural Adviser to the Comptroller of Development and Welfare in the West Indies. Assistance in the proper financing of the scheme was forthcoming from Colonial Development and Welfare funds, and the Government of Jamaica agreed to provide a working advance account.

Theoretically, a start was made with the new scheme on 1st April 1943, but for some reason it appears that the need for a valuation of the property was not appreciated and no valuation report was prepared. A two-year period of muddling and misunderstanding followed and the scheme continued to be operated at a loss. The position was again reviewed on 31st March 1945.

A memorandum of the scheme was prepared by Mr. A. J. Wakefield and this was approved by the Executive Council of the Government of Jamaica. The memorandum was printed for the guidance of all concerned in the scheme. The Committee to manage the project was reconstituted in accordance with the terms of the printed memorandum. A valuation report was prepared. Government agreed to write off the net cash deficit and to continue to provide a working advance account.

A fresh start was made on 1st April 1945 by which time the membership of the community had been reduced to the original members of the Walkerswood Pioneer Club and a few members of the other, now defunct, pioneer clubs. The total membership was 31. Eight wooden shacks had been erected to house workers on the property but none of these, now dilapidated structures, was occupied except by casual workers on the property.

The members, in addition to supplying labour had their own farms in outlying parts of the property and on some of these farms the members were actually employing labour to work them. Twenty-two head of cattle, owned by individual members, were allowed to run with the co-operative herd. Members found their own markets for their own farm produce, some selling milk to the Condensery. The whole set-up was a travesty of the collectivist farm, which had been the objective of the new scheme.

Since the fresh start, however, abuses have been removed and there has been a steady growth of understanding and confidence in the scheme, which is reflected in the balance sheets for the years 1945-46 and 1946-47.

Financing of the Scheme

From C. D. & W. funds, the sum of £19,835 was approved for the Lucky Hill Community Project in 1942. In this sum was included £500 for the establishment of a Trades Training Centre. Subsequently this £500 was transferred to assist in the establishment elsewhere in Jamaica of a training centre for leaders for the 4-H Club Organisation.

From the approved sum, Government took £4,100 with which to purchase the property which it has let to the Community. At present no rental is charged but, although no pronouncement has yet been made, it is anticipated that the annual rental will be 3% of the purchase price of the property and it will be instituted as from 1st April 1948.

From the balance of the approved sum, funds were allocated as follows:—

£7,500—As a loan to the Community to build houses and for no other purpose can it be used. The estimate was prepared in 1942 and the sum was considered to be adequate for the provision of 75 houses, but with soaring prices and wage rates four times the sum would be required. The loan is to be refunded to the Government of Jamaica over a period of 30 years if payment is not effected at an earlier date. The rate of interest is 3% of the loan outstanding.

£5,000—A grant to the Community to assist in the capital development of the property. The grant is allocated under sub-heads. In all there are 13 sub-heads and alterations within sub-heads is only possible with the prior consent and approval of Government. This inelasticity of sub-heads has proved to detract from the development programme and recently approval of the Secretary of State has been sought for the reduction in sub-heads to five in number thus:—

1. Farm buildings.
2. Livestock.
3. Machinery and equipment.
4. Light and Water supplies.
5. Development of property.

£2,285—To cover the salary of an Overseer and Assistant Overseer with war bonus during a five-year experimental period 1943-48. The experimental period will obviously have to be extended and this allocation will require to be reviewed.

In addition, the Government of Jamaica has provided an advance working account of up to £3,000 to be drawn upon as required. Advance for this working account will be repaid from the Share Capital Account about to be subscribed by members in shilling shares.

Management

The project is at present managed and controlled by a Managing Committee working through a Settlers Council. This Managing Committee is appointed by the Governor and consists of nine persons:—

(a) A nominee of the Director of Agriculture (Chairman).

(b) A nominee of the Financial Secretary and Treasurer.

(c) A nominee of Jamaica Welfare (1943) Ltd.

(d) Three persons residing in the neighbourhood of Lucky Hill, selected by the Governor.

(e) The chairman of the Settlers Council and two representatives nominated by the Council annually.

Broadly, the functions of the committee are, in consultation with the Settlers Council, to lay down objectives of the project, determine and submit plans of work and estimates of expenditure for capital development and the ordinary working of the project for the approval of Government, to have brought into proper account all monies placed at the disposal of the committee, to see that all finances are administered on approved lines, to control the work of the Overseer, and to prepare an annual progress report for public information. The committee meets quarterly.

Much of the work of the committee is devolved upon an Executive Sub-Committee which is responsible for ensuring that the policy of the Managing Committee as approved by Government is properly administered. The Executive Committee is composed of the Chairman of the Settlers Council and the three Lucky Hill area residents. The Settler is Chairman of this Committee. The Overseer is in regular contact with the members of this Executive Committee

but to ensure adequate supervision, the Committee meets regularly once per fortnight. At these regular meetings the Department of Agriculture is represented in an advisory capacity.

The Settlers Council consists of a Chairman and ten members who are elected annually by vote at a general meeting of the settlers. The functions of this Settlers Council are with the advice and guidance of the Executive Committee.

(1) To be responsible in the Council's interest for the good conduct of the members of the project.

(2) To determine whether new members shall be admitted and select and nominate new members for approval by the Managing Committee.

(3) To dismiss undesirable members.

(4) To determine the allocation of the annual dividends.

(5) To ensure that all operations required by the Overseer are properly carried out.

(6) To make rules of procedure for the proper administration of the project and to see that the rules are properly obeyed.

(7) To ensure that the earnings of all members are properly recorded.

(8) To appoint sub-committees to deal with social welfare and club projects.

This Council meets monthly. As the Chairman of the Council is also Chairman of the Executive Committee, there exists a strong link between the Managing Committee and the Council, and through the Executive Committee, any suggestions from the Council are given early attention.

For the purposes of education in the details of the scheme, the settlers, at their own request, hold a general meeting every month at which various members of the Managing Committee and Officers of Jamaica Welfare are invited to be present to take part in the discussions and deliberations. This machinery for the administration of the project may, at first, appear somewhat cumbersome, but it can be reported that it is effective.

Financial Administration

This falls under two heads :—

(a) Administration of Finance from C.D. & W. funds.

(b) Administration of Advances from Working Capital.

All details of administration of funds under the two heads are carefully set out in detail in the Wakefield memorandum on the Scheme. All accounts in connection with expenditure from C.D. & W. funds are kept by the Department of Agriculture and are operated through the accounts branch and overseer in charge, on prescribed Government lines. Quarterly statements of expenditure are submitted to the Managing Committee. This Government accounting will be continued until the capital grant has been fully expended and until all transactions in connection with the housing loan have been completed.

The administration of the advances from the working account is under the control of the Managing Committee, which operates its own bank account. Advances to this account are made in such sums as are approved by the Director of Agriculture. All revenue for the working of the project is paid into the account, so that advances can be kept to minimum immediate requirements. Until such time as all advances have been repaid, Government has insisted that sums can be withdrawn from the Community's bank account only by cheques under the signature of a member of the Managing Committee and a Department of Agriculture Accountant. The Accountant was required to be duly nominated as the Accountant and Treasurer of the project and to be bonded in a sum of £300 by the Community. The bonding was done through an Insurance Company. An internal auditor of the Department of Agriculture checks the books regularly and the books are also subject to Government audit. The Managing Commitee is required to prepare and submit to Government a balance sheet and profit and loss account annually.

Duties and tasks are assigned to members of the project by the overseer. Two members, at present act as headmen and one as storekeeper. Wages are paid at the current rates for labourers on neighbouring properties. A strict account is kept of each man's earnings and wage bills are paid fortnightly. Because of capital developments and the still undetermined labour capacity of the project, it is still necessary to employ a certain number of labourers who are not members of the project. The labourers are paid at the same rates as the members. It is realised that this state of affairs is undesirable, and as soon as possible, work on the project will be restricted to members only with assistance from the wives and children of members during rush periods, such as times of harvesting. Regular labourers, however, are now applying for membership and well tried men who have proved their worth to the satisfaction of members are being accepted.

The Managing Committee, in collaboration with the Settlers Council, submitted the following method of distributing profits which was approved by the Governor.

(a) 10% to a General Purpose Reserve Fund.

(b) Remainder as dividends to members in strict proportion to earnings for work done and paid for from the working account during the year in respect of which the dividend is payable. Two-thirds of the dividend is payable to individual members in cash and one-third in the form of one shilling shares. These shares will gradually offset all advances made by Government, until the Government working account is cleared and is replaced by share capital.

Membership

New members are selected by the Settlers Council after consideration of written applications and with due knowledge of the applicants, and are elected only after approval by the Managing Committee. The entrance fee, decided upon by the settlers, and approved by the Committee is 2s. 6d. Before a man is

elected finally he has to serve a three months' probationary period to the satisfaction of the Council and before he has a vote in the general meeting, he must have purchased a minimum of five shares. Thereafter, he is entitled to the rights and privileges of all members, but the continuation of his membership is subject by his abiding by all the rules. He is required to live on the property, as soon as accommodation can be provided. Priority in the allocation of houses has been given to married men with families. Provision is being made for single men to share houses. No concubinage is permitted.

A member may resign from the project on giving two weeks' notice in writing. A member may be expelled if three quarters of the members decided that such action is necessary, or if three quarters of the members of the Settlers Council, present at a special meeting summoned for the purpose of considering expulsion, decide that such action is necessary. Any person ceasing to be a member, will have his share capital refunded, but will forfeit all claims to dividends, interest due on shares and to rights, privileges and obligations of membership. In the event of a person dying or becoming incapacitated, his shares, together with all interest and profits due to him, will be paid over to him or his heirs. The successor to any past member, can only be appointed by the Council with the approval of the Managing Committee.

Capital Development 1943-47

(a) *Housing*—By the end of the 1946-47 financial year, the amount of the housing loan which had been expended was £2,782. 4s. 0d. For this sum the community then owned :—

One Overseer's house—verandah, lounge, dining room, two bedrooms, bathroom, kitchen, servant's room and garage.

One Assistant Overseer's Cottage—verandah, 3 rooms, kitchen, bathroom, servant's room.

8 Wooden shacks—2 rooms, kitchen separate and pit latrine.

14 Cottages—verandah, 3 rooms, with kitchen, bathroom and pit latrine separate.

For some unknown reason £300 of the cost of the Overseer's house was met from the capital grant. Most of the cottages already built and all to be built in the future, are of a uniform type. The house has a wooden framework supported on stone pillars, floors are of wood, walls of Spanish walling (marl, stone and white lime) faced with lime plaster, roof of shingles or sarking and paroid roofing, verandah and steps are of concrete. The two bedrooms are 10' x 10' and the living room 14' x 10', verandah 6' x 10'.

The cost of the first six cottages built in 1944 was £130 each. Contractors' estimates for the construction of the same type of cottages in 1946 varied from £500 to £750. By extracting all possible materials, lumber, marl, stone and lime on the property and supplying these at cost only, selling cedar and replacing with cheaper hardwoods for certain purposes and by paying for clearing operations, levelling sites, and transporting materials from the working account, it was possible to bring costs down to £260 per cottage and eight were erected for this average price in 1946-47. The average price will be further reduced by the sale of roofing shingles about to be sawn on the property and which would normally have been used on the cottages. The building programme is being continued as materials are extracted and prepared ready for use.

All housing has been insured by the Community against fire, hurricane and earthquake damage. The annual premium in respect of the present houses is £88. 13. 2.

(b) *Development under Capital Grant.* The amount expended from the £5,000 capital grant, to 31st March, 1947 was £3,445. 17. 5. Development and purchases from this grant under five sub-heads are as under .—

1. Farm buildings—£924. 3. 1.—for office, tools and equipment store, crop store and drying shed with movable trays, two cow sheds, two bull pens, housing for saw bench, engine, chaff cutter and grinder, implement shed, dipping tank.

2. Light and Water supply—£390. 10. 2.—for catchment, water tank and piping.

3. Livestock—£499. 18. 4.—for dairy and beef cattle.

4. Machinery and equipment—£358. 14. 0.—for 12 H.P. Horizontal Diesel Engine, ploughs, harrows.

5. Development of property—£1,272. 11. 10.—for pond reclamation, roads, walls and fences, afforestation, land reconditioning, planting of coconuts, citrus and avocado.

The lease included the taking over of beef and dairy cattle, draught stock, and pigs to the value of £1,371. 15. 0. and dead stock to the value of £132. 0. 0. These figures are arrived at from the valuation made on 31st March 1945, which, it must be stressed, was the first valuation carried out, and the expenditure from capital grant during the 1943-45 period. The items are in the nature of salvage by the Government from a financial wreck and they may yet be subject to revision.

The balance of the grant, will, by no means, cover the development which is projected nor was it ever intended that it should do so. The grant was intended to assist only in getting the project started along its road to success. It should be pointed out that pending further information from Government no insurance is carried in respect of farm buildings, equipment, live and dead stock.

Policy and Working Plan

No detailed map or plan of the area is yet available. A very rough estimate of the possible division of the lands is :—

Existing woodlands or suitable only for afforestation	—	300 acres
Arable lands	—	150 „
Pastures	—	300 „
Permanent Crops	—	50 „
Building sites, roads, ponds, reservations for settlers gardens etc.	—	73 „
		873 acres

One of the objectives of the Committee is to demonstrate to the settlers maximum efficiency in land utilisation within the boundaries of the property. A detailed plan to guide this work is necessary and is in course of preparation. It is not feasible to alter field boundaries to any great extent but areas within present boundaries suitable for arable cultivation, pasture, permanent crops or afforestation are being demarcated and areas measured. It is hoped gradually to build up a composite plan of the whole property, to guide development, to ensure accurate recording, and to facilitate replacement by a proper rotational system, the past practice of what is tantamount to shifting cultivation within field boundaries.

Arable Crops.

During the 1945-47 period the greatest area under cultivation at one time has been about 100 acres. Crops which have been found to do well and to be profitable to grow are :—

Roots —Cassava, cocoes, potato, sweet potato.

Grains —Red and yellow maize.

Pulses —Red peas, black eye peas, cow peas, soya beans and peanuts.

Vegetables—Miscellaneous but with pumpkins exceptionally good.

The production of these crops is to be continued and the time has come for the introduction of fodder grasses into the crop rotation.

Small areas of plantains and pineapples have done well and some extension of these plantings will be undertaken.

Permanent Crops.

Tahiti seedless limes were planted in 1944 on very poor shallow soils. This venture was a failure. The citrus orchards of Marsh Seedless grapefruit, Parson Brown and Valencia oranges will be extended as these crops are all doing well. No extension of the avocado pear plot is contemplated at the present time. Coconuts are quite promising in certain portions, but the property is at an elevation of 1,000 feet and therefore rather high for coconuts. 2,000 selected seed nuts have been sprouted in a nursery for planting out in avenues or for sale to nearby small holders who are anxious to obtain supplies. One part of the property is suitable for cacao and here it is proposed to establish at least seven acres of the Trinidad I.C.S. Nos. 1, 6 and 8. Breadfruit will be used in providing a windbreak.

Afforestation.

In 1945 some 6,000 Mahoe (*Hibiscus Elatus*) were planted in a roadside section. Trees are doing well particularly where some under-cultivation is practised. The mahoe plantation will be extended and possibly some cedar and mahogany will be introduced. The effects of the 1944 hurricane are still apparent, and there is yet no shortage of firewood, but the establishment of fuel plots is necessary and *Cassia Siamea* will be used for this purpose.

Livestock.

Pigs in large numbers have not proved profitable at Lucky Hill and now only one sow is retained. Service for the sow is obtained locally at a recognised fee of one boar piglet of the litter. Only vegetable waste and unsaleable crops are fed to the sow, and piglets are sold off as soon as they are weaned.

There are no other kinds of small stock on the property except a few poultry, owned by individual settlers, but the possibilities of extending small stock husbandry are being considered by the Committee.

One of the main concerns of the Committee during the 1945-47 period, has been the evolution of a cattle policy with the assistance of the Department of Agriculture's Livestock Officers.

The herd was separated into a milking herd of 24 cows and 24 heifers. Guernsey, Jersey, Holstein and Indian bloods are present in varying degrees in the foundation stock, but the policy is to breed up to as high grade of Guernsey as local conditions will permit. A pure bred Guernsey bull was obtained on loan from the Department of Agriculture for use with this herd.

The pedigrees of all but two of the milch herd have been obtained and the recording and filing of pedigrees have been reduced to some semblance of order.

All bull calves are sold to the butcher. Heifer calves are hand reared. Evening milk is fed to calves and purchased by settlers. Morning milk, apart from the calves requirements, is sold to the Condensery. A Condensery route passes through the property. Nearly £240 was obtained from the sale of milk at 4d. per quart in 1946-47 but dairying can be increased very considerably and policy is directed towards this end. It is intended to stall feed all cows in milk, except for a short period every day, for exercise and foraging for those weeds which appear to keep the cows' systems properly toned.

The remainder of the herd is being run on pastures as a beef herd. Culled dairy type of animals are not being bred and are being fattened for sale for slaughter. There are 18 high grade Red Poll cows and a grade Red Poll bull was purchased for use with these Red Poll cows only.

In 1946 all animals, including those of the settlers, which are still being pastured on the property, pending the development of the housing programme, were tested for Tuberculosis and Contagious Abortion. All were free from Tuberculosis, but six animals, suspected of having Contagious Abortion were sold to a butcher. Contagious Abortion vaccination was carried out. All calves were vaccinated against blackleg. At 31st March, 1947, the number of animals in the two herds were :—

	Bulls	*Cows & Heifers*	*Heifer Calves*	*Bull Calves*	*Total*
Milking herd	—	48	16	3	67
Beef herd	1	26	8	4	39
					106

Draught animals on the property at 31/3/47 were 8 working steers, 13 mules and 2 horses. The valuation of the livestock at 31/3/47 amounted to £2,052, and the community had accumulated the sum of £310. 13. 5. from the sale of foundation stock. This sum has been kept in a separate account and is to be used for buying good type animals if and when such should become available for purchase.

The economy of the project then, is built up on a balance of field and permanent crops, dairy and beef cattle, with particular emphasis on dairying. Subsidiary, though remunerative items are the extraction of lumber and the operation of a saw mill and the extraction, preparation and sale of marl and lime. Wild citrus and pimento in the pasture lands also help to increase the income. In 1946 some ecuelling of citrus oil from the wild citrus was undertaken.

Profits 1945-47

The committee members share the view that the approach to the settler's soul, as is the case with farmers the world over, is easiest through his pocket. Every effort has been made towards guiding the members to show a profit on the working of the project. The profits have been small but the response of the settlers to this change from their past experience, has been marked. Meetings have been fully attended and great interest in everything connected with the project is being evinced. This remark, furthermore not only applies to the settlers. Public interest is increasing greatly. Below are shown the expenditure from the Working Account on wages to settlers and the amount and distribution of the profits for the two years 1945-46 and 1946-47.

1945—6 : Total Wages, £841. 12. 2.; Profits £76. 9. 9.; Reserve £16. 13. 1.; Distribution (Share Capital £19. 12. 0.; Distribution (Cash), £40. 4. 8.

1946—7 : Total Wages, £767. 5. 5.; Profits £194. 14. 1.; Reserve, £19. 10. 5.; Distribution (Share Capital) £58. 8. 0.; Distribution (Cash) £116. 15. 8.

Twenty-four members received a share of the 1945-6 profits. Seven members resigned early in the year and forfeited their right to a share in the dividend. Their portions were paid into the reserve account. The profits for 1946-7 will be shared by 26 members. In addition to these 26 members, there were at 31/3/47 eight new members, who were serving their three months probationary period. Results for 1947-48 should prove much more encouraging from the financial aspect and the operation of the newly installed saw mill will help to swell the profits.

Projected Capital Expenditure

The need for more rapid capital devolopment is becoming apparent to the settlers themselves, and steps to speed up the subscription to share capital are being considered. Projected capital works under subheads are as follows :—

Farm Buildings—Cattle stalls for milking herd, four bail milking system, dairy, calf nursery, stable and harness room, new bull sheds, forge, new drying trays, pit silos, extension of dipping tank.

Light and Water Supply—Wiring of houses, office, sheds and various farm buildings and wiring to source of water supply. Pipe line from Venture River to catchment tank and gravity feed pipes to various points on the property.

Machinery and Equipment—Electrical dairy apparatus, water pump, grinder, chaff cutter, 10 H.P. Rotary Hoe, Autoscythe, saw blades, cross cut saws.

Development of Property—Further pond reclamation and roads to housing sites, land reconditioning, soil conservation measures, further sub-division of pastures, burial ground, extension of afforestation and orchard crops.

Social Welfare Activities

Recreation.—A cricket pitch has been rolled out and members have been able to obtain some second hand gear. Several dances and sports days have been held.

Canteen.—A canteen is run by the sub-committee of the Settlers Council. This present system is not satisfactory, but assistance in developing this activity into a properly constituted buying club has been promised by officers of Jamaica Welfare.

Sick Benefit.—A sick benefit society was run by the Walkerswood Pioneer Club. The Walkerswood Club has now been merged with the Lucky Hill Community Project and its funds of over £25. 0. 0. have, at the request of the members of the Walkerswood Club, been handed over to the Community Project. Membership is compulsory and the compulsory subscription is 1/- per month. New members are eligible for full sick benefit as soon as they have paid their first subscriptions. Any member forfeits his right to receive benefit if he is not in good standing with his subscriptions. This sick benefit society is run by a sub-committee of the council, assisted at the general request of the settlers by one lady member of the Managing Committee.

Arts and Crafts.—Officers of Jamaica Welfare have promised assistance in the training of the wives and daughters of settlers in home crafts. Arrangements are in train to hold fortnightly meetings and demonstrations and form working groups.

Agricultural Shows.—Members have taken a full and active interest in the district agricultural shows. At a recent show the Community obtained 11 first and 13 second prizes.

This account of the Lucky Hill Community Project, tracing its history, illustrating its development and progress, setting out its plans for the future, indicating possible ramifications, may be somewhat lengthy but as it is the first experiment of its kind in the British West Indies, it is possible that a report of this detailed nature may furnish information which ought to be presented to the public. The Lucky Hill experiment may provide a part answer to the very vexed and complex problem of land settlement with which Jamaica is faced at the present time. If this article only invokes criticism of the right kind, it will partly have served its purpose, for constructive criticism will be welcome by all who are concerned with the well being of this scheme.

Before any extension is considered, it may be thought necessary to repeat this form of experiment elsewhere. In concluding this article it may therefore be expedient to give a few suggestions, based on experience of some of the difficulties which have been encountered at Lucky Hill.

Settlers.

The men should be very carefully selected by an appropriate authority. The aim also should be to have a range of age classes, with emphasis on the younger classes and to have a fairly high proportion of literate members.

At Lucky Hill the age classes are very limited and, at the present time the average age is perhaps too high. The election to membership of new younger men will be encouraged. The proportion of illiterate members is much too great to permit of easy devolution of accurate recording. Only a few members have any knowledge of the three R's.

Housing.

Accommodation should be provided for settlers right at the start of operations. There can be no community centre until there are adequate numbers of houses for the settlers. It should be made quite clear that the houses are for all time the property of the community and can never belong to the individual. At Lucky Hill it has been necessary to cater for the psychology of the settler, by allowing him about half an acre of land around the house he occupies, on which to grow vegetables for his household, to rear chickens, and to keep, if he desires, a cow, with the proviso that all these individual activities are confined to the half acre of land.

In some parts of West Africa, the purchase of a cow or a sheep is a transaction which is in the nature of the taking out of an insurance policy. This same idea is held by the settlers at Lucky Hill. Another point in favour of this arrangement is the fostering of the pride of the individual in his garden or his cow, though it is recognised that economically it would probably be sounder to conduct all these individual activities on the co-operative basis of the whole project.

Supervision.

The necessity of extending the experimental period was mentioned early in this article. It is suggested that there should never be any question of withdrawing the overseer after a short experimental period. Eventually, a community might undertake to educate one of its sons to fill the post. His wages or salary should be paid from the working account and he could receive, in recognition of good work, a bonus, to be paid from the divisible profits. Meanwhile the way could be prepared for such a step by Government claiming from the profits of a scheme which is making good progress, a percentage of the profits to help to defray the costs of supervision. If eventually, the chairman of the settlers with his council, can conduct all the administrative side of the undertaking, he will have his time fully occupied and an executive authority, in the person of a salaried man would appear to be a desirable provision for all time.

Financial Administration.

As set out in the Wakefield memorandum, the financial administration of the Lucky Hill Community Project is straight-forward and simple. In actual fact it is still proving cumbersome and unwieldy due to the failure of Government to implement fully the approved policy. It is suggested that before any new experiment which may be conducted, the financial machinery should be properly fuelled, lubricated and geared before it is set in motion. Long, undue delays in an experiment, which is largely one in psychology can only be dangerous and militate against success.

Knowledge, Understanding and Sympathy.

This, the last suggestion, is the most important of all. It is impossible to stress too strongly that all who are in any way to be connected with any future similar experiment, should, before operations commence, have a full working knowledge of the scheme in all its aspects. All factors, all implications should be thoroughly understood and only those who are in full sympathy with, and have every confidence in the scheme should be entrusted with the task of sharing the duties associated with its early administration.

Addendum to Paper on the Lucky Hill Community Project, Jamaica

The above paper was submitted in July, 1947, and because of delay in printing the Editor has asked that some of the information which was provided should be brought up to date.

The amount sunk in the project and the present capital value can best be shown by the Balance Sheet for 1947-48, given hereunder :—

Revenue for the first three months of 1948-49 amounted to £1,100.11.10d. (inclusive of extracted building materials not yet credited to Revenue); £882.0.6d. of the Quarter's Revenue was derived from the sale of food crops.

The details of revenue for 1947-48 were :—

	£
Sales of Food Crops	984. 0. 8
Citrus	66.14.11
Miscellaneous Crops	23. 8.11
Milk	292.19. 5
Cattle	406. 0. 0
Pigs	11. 0. 0
Rent Charges	32. 7. 7
Pasturage Fees	13. 6. 6
Entrance Fees	3. 2. 6
Property Materials (including all materials such as stone, marl, lime and lumber, extracted at cost and handed over to Building & Housing programme)	778. 0. 8
	£2,611. 0. 8

BALANCE SHEET AS AT 31ST MARCH, 1948.

Liabilities			Assets		
Housing Loan		£4,810.11. 4	Lands		£4,061. 0. 3
Capital Grant for Development		£4,223.19. 7	Permanent Crops		573. 5. 9
Capital Leasehold :—			Housing & Farm Buildings		7,720.13. 3
Lands	£4,061. 0. 3		Livestock (Appendix A)		
Buildings	820. 0. 0		Beef Herd	£ 736. 0. 0	
Livestock	1,481.16. 8	6,362.16.11	Dairy Herd	1,254.15. 0	
			Working Herd	562. 0. 0	
Island Treasurer—Balance on advances		1,442.17. 4	Fattening Herd	123. 0. 0	
Reserve Fund		16. 6.11	Small Stock	7. 0. 0	2,682.15. 0
Share Capital		20. 0. 0	Tools & Equipment		66.18. 3
Profit & Loss Appropriation A/c :—			General Development of Property		993.15. 4
Net Profit 1946-47	£ 54. 8. 4		Unreaped Crops (Appendix B)		812.12. 8
Net Profit 1947-48	401.13. 6	456. 1.10	Stock on Hand :—		
			Property mat.	£333. 7. 4	
			Crops	76. 8. 7	409.15.11
			Bags on Hand (to be returned)		8.15. 0
			Treasurer (Cash in hand for entrance fees)		3. 2. 6
		£17,332.13.11			£17,332.13.11

The figures given under *Profits* 1945-47 should be amended to read—

	Total Wages	*Profit*	*Distribution* *Revenue*	*Share Capital*	*Cash*
1945-46	£841.12.2	£76.9.9	£16.6.11	£20.0.0	£40.2.10
1946-47	767. 5.5	54.8.4	(not distributed until April, 1948).		

The programme of capital development of the property has now consumed the whole of the £5,000 capital grant made from Colonial Development and Welfare funds. The number of cottages erected is now 26 and the balance in the Housing Loan is under £2,000.

Membership has increased to 33 plus 8 men who are still serving the probationary period. The probationary period has now been extended to six months.

There can be no doubt that the project, planned by Mr. A. J. Wakefield and with modifications introduced in the light of experience, is succeeding. Attention is becoming focused on the possibilities of this form of land settlement in Jamaica. Opposition to this scheme is only from ignorance of the true facts of the scheme. A recent notable visitor to Lucky Hill, Dr. Jones, President of Earlham College, U.S.A., voiced the opinion that the approach at Lucky Hill to the problems of Government, Capital and Labour were perhaps more fully and better conceived than in any of the many co-operative schemes in various parts of the world of which he had knowledge.

J. W.
Senior Agricultural Officer.

Appointment of Farm Manager

Applications are invited from men with agricultural qualifications (degree or recognised diploma) and practical experience of farming in the tropics, for the post of Manager of the new 300 acre farm which is now being established at this College. He will be required to take over the development and running of this farm along with the other farming land at the College.

The salary will be £500 per annum, on an incremental scale, with variable cost-of-living allowance at present £135 per annum. A house will be provided rent free on the farm, in which the Manager will be required to live. Superannuation under F.S.S.U. Long leave : every three years. Passages will be provided for the Manager, his wife and, under certain conditions for his children, on appointment, on long leave and on termination of appointment. Free medical attention, and for wife and family under specified conditions.

Applications should be submitted without delay on forms which can be obtained from the Bursar, Imperial College of Tropical Agriculture, St. Augustine, Trinidad, British West Indies, or from the Secretary, I.C.T.A., 40, Norfolk Street, Strand, London, W.C.2, together with further particulars of the duties of the post.

31st December, 1948.